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Pedro Arezes *Editor*

Advances in Safety Management and Human Factors

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Preface

Safety Management and Risk Prevention is a common thread throughout every workplace, yet keeping employee safety and health knowledge current is a continual challenge for all employers. Safety Management and Human Factors is a cross-disciplinary area concerned with protecting the safety, health and welfare of people engaged in work or employment. The book offers a platform to showcase research and for the exchange of information in safety management and human factors. Mastering Safety Management and Human Factors concepts is fundamental to both the creation of products and systems that people are able to use and for work systems design, avoiding stresses and minimizing the risk for accidents.

This book focuses on the advances in the Safety Management and its relationship with Human Factors, which are a critical aspect in the design of any human-centered technological system. The ideas and practical solutions described in the book are the outcome of dedicated research by academics and practitioners aiming to advance theory and practice in this dynamic and all-encompassing discipline.

A total of six sections are presented in this book:

I. Accident Analysis and Risk Prevention
II. Culture and Organizational Aspects
III. Applications in Safety Management and Loss Prevention
IV. Safety and Ergonomics
V. Fatigue and Performance
VI. Safety and Prevention Management

Each section contains research papers that have been reviewed by members of the International Editorial Board. Our sincere thanks and appreciation to the board members as listed below:

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We hope that this book, which is the international state-of-the-art in safety management domain of human factors, will be a valuable source of theoretical and applied knowledge for global markets.

July 2017 Pedro Arezes

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Applications in Safety Management and Loss Prevention

Accident Analysis and Risk Prevention

Case Study in Best Practice Incident Investigation

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Abstract. The Workplace incident investigation methodology has typically developed alongside our understanding of accident causation and the ever-evolving associated models. The research-practice gap that has existed and continues to exist, presents an interesting area for discussion and future research. Through analysis of literature in the field of incident/accident investigation methodologies, this paper focuses on a number of models in the context of practice within a small to mid-sized enterprise and in particular looks at what can be considered as best practice for such an enterprise.

Keywords: Incident investigation methodology · Accident causation models · Linear models · Non-linear models · STAMP · Swiss Cheese Model

1 Introduction

This paper examines different models and methods for accident and incident investigation, with the goal of making suitable recommendations for a 'Best Practice' solution for a mid-size company which employs approximately 80 personnel. Preliminary results of this examination suggest that there may be no 'one-size-fits all' solution to providing a method of investigation to an organisation (of any size) and that to answer the question of; "what is best practice?" may require consideration beyond an organisation's size to provide better guidance on model/methodology selection.

2 Methodology

To perform an analysis with the aim of determining what is best practice in regards to incident investigation methodology, it was necessary to perform a search of academic articles to enable a thorough examination of contemporary approaches. To do this, a strategy of selecting databases likely to yield peer-reviewed journal articles was employed. This strategy involved initially searching The University of Newcastle's Library NEWCAT+ database, then with further concentration on academic journal databases such as ProQuest and ScienceDirect.

For the purposes of refinement, during the search for relevant peer reviewed journal articles, a number of key words and terms (see Table 1) were used to help return relevant articles. In addition to this, a number of filters were applied, such as limiting

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Table 1. Key words & terms used in searching databases

Incident	Investigation	Bow Tie
Accident	Efficacy	Multilinear events
Model(s)	Fault Tree	Events
Analysis	Fault Tree Analysis	Conditions
Linear	Non-Linear	Methodology
Swiss Cheese Model	SCM	STAMP
Causal Factor Charting	Charting Chronology	

articles to post 1990 (for contemporary articles), seeking only peer reviewed articles, selecting specific journals and selecting only full-text articles.

Not all of the articles returned through searches were suitable for the purposes of this paper and so were excluded from the discussion and analysis. Items such as non-peer reviewed articles, non-English language articles, and those that did not accurately reflect the topic (best practice incident/accident analysis methodology) were eliminated from consideration in this analysis. The initial number of articles selected for review prior to inclusion for discussion was thirty-eight. This was further reduced to 9 articles for the final review and inclusion in this paper.

3 Discussion

In exploring the ways in which an incident investigation can be conducted and analysed, it becomes abundantly clear that there are many different models, methodologies and proprietary systems available to safety practitioners and researchers alike [1]. In part, this variance in methodology or model utilised reflects the lack of a unified approach to accident causation theory in general [2]. This variety not only points to the fact that there is no single solution to all industries, companies, or over geo-political, or other social and technical boundaries, but that with such variety, it is likely that there is a disconnect between the growth areas of research and practice [3]. This variability and variety has implications for both; the potential need to employ more than one approach to satisfy the needs of a single organisation, and what is defined as best practice [4].

Due to the nature of this paper and it's intent and constraints, it will not be possible to discuss all methodologies of incident investigation/analysis that are in use today. It is however the intent of this paper to provide an overview of some approaches within the area and to provide recommendations regarding methodologies for a company with approximately 80 employees.

An incident investigation can be divided up into two distinct phases. The first phase is focussed on the data gathering activities, which produces an array of information or data. The second phase is the analysis of that data. Although there is a degree of commonality amongst data gathering activities, some of these activities and their associated outputs will naturally be influenced by several factors including investigator bias (as a result of things such as knowledge, prior experience and training) and of course, to some extent the model of analysis and it's required inputs and outputs [4, 5].

Traditional views of accident investigation follow what may be regarded as a sequential or linear pattern, such as in the case of methodologies based on Heinrich's Dominoes theory [1]. Within the research literature, many sequential models are criticised for being overly simplistic in their ability to analyse incidents that occur within complex systems, or incidents with more than one root cause [1, 3]. Despite their seemingly simplistic view, these approaches have remained in use to varying degrees [3]. Advances in accident investigation have led to multi-linear approaches to incident investigation and allow for more contributory or causal factors to be identified [6]. However, they may have limited value in analysing more simplistic incidents, which are typified by low impact – high frequency events [3, 7].

The Swish Cheese Model (SCM) of accident causation is a commonly applied method within the area of investigations [8]. The model, whilst never originally being intended to be a panacea to all investigations, does provide a useable framework for both data gathering and incident analysis [8]. The SCM and its variants (e.g. ATSB) has been referred to as a sequential model [8]. Being widely used presents an opportunity for small to mid-sized businesses in terms of the likelihood that personnel, particularly practioners, but also managers and the like, will be familiar with the model and its application [1, 3]. This may mean that for a small to mid-sized business; it could be easier to embed such a process with personnel possibly being familiar with the basic tenets of theory. With the framework in apparently wide use, this could also mean that it may not be necessary for a small to mid-sized business to employ specialist practioners to conduct investigations, therefore presenting a financial benefit in reduced wages and training costs [3].

The SCM presents several benefits for investigators, and in particular for practioners. Firstly, the SCM analysis presents an output in a visual display, which offers the benefit of providing a readily understood representation of the inter-relationships between contributing factors and the events for not only those trained (e.g. safety personnel), but also for non-experts such as line managers [8]. Another area identified, in which either a company or safety practioners may benefit, is the timely generation of an investigation report compared with other methods such as forms of Systemic Accident Analysis (SSA), which may take twice as long to complete an analysis [8].

The SCM framework has received criticism on several fronts; namely that it is a sequential technique, it can be prone to oversimplifying the mechanisms and facets involved in accident causation and that, through over prescriptive application of the model can lead to incorrect conclusions [8].

More recent developments in the area of incident investigation methodology has seen non-linear models including Systemic Accident Analysis methods having gained growing attention amongst researchers [8]. Non-linear models such as Systems-Theoretic Accident Model and Process (STAMP), ACCIMAP and Functional Resonance Accident Model (FRAM) have gained prominence by addressing some of the shortfalls, common to linear sequence models [3, 6]. Non-linear models offer the promise of potentially being able to decipher in greater detail, the complex interactions that are found amongst contributory factors within incidents, through analysing incidents and the systems within which they occur in a more holistic manner [6]. It is for this reason that in general, non-linear models have been credited with being better suited to complex organisations [4].

The STAMP model, is based on systems and control theory and has been the attention of a number of articles to date [3]. Underwood and Waterson (2014) identifies within their review of the research literature available, that STAMP is currently the most widely cited of all the SAA models. Despite being the most widely cited of the SAA models, it must be understood that SAA models in general appear not to have made large inroads in terms of use across the wider safety community [8]. STAMP, although a more recent addition to the methodologies available as noted above, is worthwhile discussing as an option as an investigation methodology for a small to mid-sized business.

Research into the STAMP model and its application to incidents has shown that STAMP is effective in addressing how the complexity within a system influences accidents [6, 8]. The STAMP model acknowledges that systems are both complex and dynamic and that incidents are not the result of a singular loss of control [8]. For an investigator this systemic and holistic approach could mean that they not only find a more significant number of contributory factors in an incident, (through highlighting the interactions between system factors) that they can potentially identify more effective control measures which may otherwise not be identified by linear models [8].

The STAMP model, like any other faces limitations. The limitations found with the STAMP model can be viewed from the perspective of useability [3, 6]. SAA models such as STAMP are apt to be viewed as resource intensive from an array of perspectives including costs; associated with training in the methodology, and time taken to perform the analysis. Much of the research into the STAMP model and its efficacy has relied upon its application to large scale or low frequency-high consequence incidents, such as single and multiple fatalities, or large scale events [3, 6]. The issue then becomes one of scalability, whereby in a practical setting, it is difficult to gauge from the literature how efficient and how suitable this methodology is for more simplistic incidents [4]. In and of itself, this could raise questions about its practical application to a small to mid-sized company.

One criticism of the STAMP model is in respect to putting it into practice arises from the differences in the data gathered as an input to the analysis [6]. With the STAMP model, there is a greater amount of data required and it has been claimed that much of this data is different from traditional data gathered and utilises techniques not necessarily used by other models [6]. The implications for the differences in data and data gathering between STAMP and other techniques include increased time to ultimately generate and communicate a report of the findings, and the potential need for more specialist trained investigators [2].

Both SCM and STAMP models suffer in regards to their reliability due to their qualitative nature [8]. These models do however share a moderate level of reliability [8]. Validity, of both models has been difficult to definitively establish, which may reflect the tendency for incident investigations to contain a level of subjectivity and the difficulties in establishing internal measure for validity [8].

Both models, in their own way aim to provide answers to the why and how an incident occurred, and they also intend to allow for the identification of suitable controls to mitigate the likelihood of repeat incidents [9]. In comparing the strengths and weaknesses of SCM and STAMP together, a picture is created about what might be best practice for a small to mid-sized company that employs 80 personnel. Best practice has been defined as “a procedure that has been shown by research and experience to produce optimal results and that is established or proposed as a standard suitable for widespread adoption” [10]. This definition allows both models to be considered best practice, however to resolve the issue of which of these two models is more suitable for use within a small to mid-size company, the question may need to be viewed more from the angle of which is more fit-for-purpose? Research has shown that some organisations have looked at this very question and due to several factors, have had difficulty in adopting a single incident analysis methodology [4]. During research into Nova, a chemical processor, it was found that there was a total of eleven methodologies in use across the business [4]. The use of multiple methodologies had arisen out of the variable needs of different areas of the business [4]. From this, it can be extrapolated that there may not be a single investigation technique that is practical for use within our small to mid-size company.

Finally, in this discussion it is important to highlight some of the limitations of the research in this field in general. Many of the studies of models and investigation/analysis techniques appear to be reliant on qualitative analysis and limited sample sizes (e.g. surveys and structured interviews) and often focussed on large scale events, thereby limiting the potential for generalisation to usefulness on small scale investigations [8, 9]. Given the limitations faced by the current research and models, in particular such as those as STAMP, it would be in the best interest of researchers to concentrate efforts on testing the models on a variety of incidents, both within and external to complex organisational systems.

4 Recommendations

Through the discussion and analysis throughout this paper, the intent has been to show what would be considered best practice in terms of incident/accident investigation methodology for a company with approximately 80 employees. From the discussion, several points arise, that need to be accounted for before a model or methodology can be fully adopted or implemented within an organisation, including: size and complexity of the organisation, and the industry in which it is based and the resources available.

Further research involving a longitundinal study of both a SCM, and STAMP, whereby a standardized set of tools for each model is developed together with, standardized investigator training, that is carried out across a sufficiently large sample size of organisations that fit into the category of small to mid sized enterprises is conducted is needed.

5 Conclusion

Whilst STAMP is a model that is gaining attention and momentum within the field, it would prove difficult to implement and embed successfully within a small to mid-sized company of 80 employees, due to resource constraints (appropriately trained personnel, time allowed to generate reports) and likely incidents to be encountered (high versus low outcome). All this having being said the STAMP model should not be discounted out of hand, particularly if the organisation within which the model is to be applied is complex in nature or the organisation has the resourcing to allow for a multi-tiered system of incident investigation.

If having to provide a single incident investigation methodology to a small to mid-sized company, the discussion and this paper would recommend that such a company adopt a Swiss Cheese Model approach to its investigations. This is in line with findings by others [3, 8], due it's wide spread adoption throughout many industries, its ability to provide moderately reliable results in a timely fashion and its useability by experts and nonexperts alike.

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“Day to Day, Town to Town, Sing My Songs, Travel on”? Examining Aspects of Precarious Employment for Work Psychologists in Austria

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Abstract. Work psychologists play a crucial role in today’s work systems, where psychological stressors are on the rise. However, the occupational profile of work psychologists is not clearly defined by Austrian law and atypical employment might be common among Austrian work psychologists. In our study, we identified aspects of an undefined and insecure occupational profile and hypothesized a positive association with role ambiguity, which in turn was supposed to affect psychological wellbeing negatively. Finally, we hypothesized that well-functioning cooperation with occupational physicians would buffer experiences of role ambiguity in work psychologists. 31 experts were interviewed and salient topics served as a base for an Austria-wide online survey study with $N = 122$ participating work psychologists. Regression analyses supported the assumed effects. The results highlight the importance of a more clearly defined occupational profile for work psychologists. We discuss viable approaches to improve working conditions for work psychologists in Austria.

Keywords: Precarious employment · Work psychologists · Occupational profile · Role ambiguity · Psychological wellbeing

1 Introduction

Since the emergence of mega trends such as globalization, flexibilization, and new forms of communication and information technology, the character of work has shifted significantly from physical to mental work. Psychological stressors accompany this shift, confirmed by the considerable increase of work-related stress and associated disorders [1].

The European Union enacted a policy in 1989 [2] that pledged all member states to establish uniform minimum standards of workplace safety and health in national legislation. In Austria, the respective act is the “Worker Protection Act” [ArbeitnehmerInnenschutzgesetz]. In its last major amendment in 2013, the increase of psychological stressors has been accounted for explicitly by clarifying that the evaluation of work-related psychological stressors is an obligatory part of workplace safety and health activities.

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Although the analysis and evaluation of work-related psychological stressors is a key competence of work psychologists, the profession lacks a clear statutory basis in Austria when compared to occupational physicians and safety engineers. What's more, Austrian law remains somewhat vague in defining both the occupational profile of work psychologists and the practice of the evaluation of work-related psychological stressors, respectively. Consequently, employers in Austria are not obliged to engage work psychologists for prevention in contrast to occupational physicians and safety engineers. Although the competencies and qualifications of work psychologists encompass far more than the evaluation of psychological stressors, this in fact is the gateway for many work psychologists to receive an initial assignment and hopefully the first step for a longer-term mandate in organizations.

The fact that Austrian law does not protect the job title "work psychologist" is another aspect of legal insecurity. This impedes the establishment of clear quality standards because any psychologist may refer to him- or herself as work psychologist without having to provide evidence for a specific qualification. In summary, as work psychologists only slowly gain ground in occupational health and safety and do not yet experience appropriate consideration by the law, the definition of their occupational role is still insufficient.

2 Theoretical Background

2.1 Precarious Employment for Work Psychologists in Austria

Due to the underlying conditions summed up above, work psychologists are facing difficulties to compete in the labor market. Atypical employment is the rule since the majority of work psychologists are own account workers [3]. In absence of scientific studies examining working conditions of occupational health and safety professionals in general and work psychologists in particular, it remains unknown to what extent atypical employment relates to risks of precarity for work psychologists in Austria.

While various concepts of precarity or precarious employment have been proposed [4, 5], there currently exists no universally accepted definition. According to Keller and Seifert [6], precarious employment is characterized by the absence of one of the following four criteria: household income that ensures the livelihood, employment stability, employment ability, and integration in the social benefit system. These criteria are less likely to find in atypical employments. For example, the salary of part-time workers may not ensure livelihood or own-account workers may neglect private unemployment or pension insurance. Atypical employment may therefore promote precarity.

In this paper, we will examine how precarious employment manifests in the work life of work psychologists in Austria and how it impacts their wellbeing. In doing so, we will first describe several aspects of an undefined and insecure occupational profile for work psychologists. From a psychological point of view, we will then investigate the process of precarity as it affects human behavior and experience.

2.2 Working Conditions and Psychological Wellbeing

Working conditions are important determinants for mental health and wellbeing [7, 8]. A series of work-related psychological factors have been shown to affect psychological wellbeing [9]. In particular, job insecurity is likely to exert a detrimental influence on physical and mental health as well as psychological wellbeing [7, 10–12]. Job insecurity may refer to uncertainty regarding either the job's consistent existence (quantitative aspect) or the continuance of subjectively important job characteristics (qualitative aspect) [13]. The perception of an undefined and insecure occupational profile for work psychologists primarily relates to quantitative job insecurity, because in competing in the labor market, the continuance of the job itself is at stake.

2.3 Organizational Role Theory and Social Support

Role theory refers to specific forms of organizational behavior that are associated with a given professional position [14]. All members of an organization develop ideas and attitudes of what is appropriate and inappropriate for a certain occupational role. Therefore, the role owner faces various expectations from other organizational members (e.g., employer, colleagues) and tries to meet these expectations. Undefined role expectations (e.g., ambiguous assignments) lead to uncertainty about goals. This, in turn, will trigger regulation uncertainty, since the sequence of actions from a present state to a desired end state cannot be known if the end state is vague. It is from such goal and regulation uncertainties that role stress—i.e., role ambiguity and role conflict—arises [15].

As suggested by various (psychological) work design models [16, 17], social support is a significant work-related resource. Moreover, social support may buffer the negative consequences of role stressors on stress-related reactions [18, 19]. Interdisciplinary cooperation is an essential aspect that contributes to the success and sustainability of preventive activities. What's more, cooperation with other professionals is a valuable resource in daily work, related to both the accomplishment of tasks and the cultivation of social contacts. Hence, a positive collaboration climate among different professional groups provides social support in organizations.

2.4 Hypotheses

As explained above, we assume that work psychologists in Austria perceive their work situation in ways that are indicative of an undefined and insecure occupational profile. Drawing upon research on quantitative job insecurity [12], we expect an undefined and insecure occupational profile to be associated with reduced psychological wellbeing.

Hypothesis 1. Perceptions of an undefined and insecure occupational profile correlate negatively with psychological wellbeing.

In addition, a (legally) undefined and insecure occupational profile may lead to uncertainties pertaining to the professional role and, consequently, give rise to role stress. Since the occupational profile of work psychologists is still relatively undifferentiated and clear competencies have not been established, uncertainties and insecurities about adequate role behavior may emerge. In line with this reasoning, we suppose that the perception of an undefined and insecure occupational profile is related to increased role ambiguity. Scientific evidence suggests that more role ambiguity relates to less psychological wellbeing [8]. We therefore assume that role ambiguity mediates the relationship between an undefined and insecure occupational profile and psychological wellbeing.

Hypothesis 2. The negative effect of an undefined and insecure occupational profile on psychological wellbeing is mediated by role ambiguity.

According to research, a lack of social support affects psychological wellbeing [7, 8]. Conversely, supportive forms of cooperation lead to positive consequences, as outlined above. Occupational physicians are a well-established group and the proximity of occupational medicine and occupational psychology qualifies occupational physicians as an important role model for work psychologists. Well-functioning collaboration of occupational physicians and work psychologists is consequently supposed to act as a moderating resource capable of preventing the emergence of role ambiguity. We therefore assume a buffering effect on the positive association of an undefined and insecure occupational profile with role ambiguity.

Hypothesis 3. Well-functioning cooperation with occupational physicians buffers the detrimental effect of an undefined and insecure occupational profile on role ambiguity among work psychologists.

3 Method

The present study is the result of a project that evaluated the working situation of occupational physicians, safety engineers, and work psychologists in Austria [20]. In a first step, we interviewed 31 experts (practitioners, representatives of professional groups, social partners, policy makers). The interview data were then subjected to qualitative content analysis in order to identify relevant topics of the working situation. Salient topics served as a base for an Austria-wide online survey study across all three professional groups. This article focuses on the data of work psychologists who participated in the online survey study.

3.1 Sample

Data were gathered from $N = 122$ Austrian work psychologists. Participants were recruited by email with help of two associations of the professional group of Austrian psychologists. Respondents had a mean age of 42.01 years ($SD = 8.86$, range: 25–66) and were predominantly female (71%). The majority were own-account workers (57%), whereas employed work psychologists mostly had permanent contracts (88%). 68% of the participants reported work psychology as their main profession, the remaining 32%

referred to work psychology as their secondary profession. Mean job tenure was 9.14 years (*SD* = 7.10, range = 1–35).

3.2 Measures

Since the survey study required the generation of items customized to the specific working situation of work psychologists in Austria, only few established scales could be employed. The self-generated items were subjected to exploratory factor analysis to identify patterns of interrelated variables. These patterns were then labeled *undefined and insecure occupational profile* and *cooperation with occupational physicians*, respectively, and aggregated to form unweighted additive indices [21].

Undefined and Insecure Occupational Profile. The index comprised eleven self-generated items that were to be rated on a five-point response scale (from 1 = *no, not at all* to 5 = *yes, definitely*). Complete item wordings are given in the Appendix (Table 5). Internal consistency was good (Cronbach's alpha [α] = .82).

Psychological Wellbeing. The WHO-5 Well-Being Index [22] was used. Apart from measuring psychological wellbeing, this instrument is also appropriate to screen depression [23]. The five items (example item: "during the last two weeks, I have felt calm and relaxed") had to be rated on a six-point response scale (from 1 = *at no time* to 6 = *all of the time*). Internal consistency proved to be good to excellent (α = .87).

Role Ambiguity. Role ambiguity was measured with three items (example "I know exactly what is expected of me") of a well-established role stress questionnaire [24]. Items were to be rated on a five-point response scale (from 1 = *no, not at all* to 5 = *yes, definitely*). Item scores were reversed prior to the analysis. Internal consistency of the scale was acceptable to good (α = .78).

Cooperation with Occupational Physicians. This index consisted of four items that had to be answered along a five-point response scale (from 1 = *no, not at all* to 5 = *yes, definitely*). High values on the scale represent work psychologists' appraisal of the cooperation with occupational physicians as useful and well-functioning. Complete item wordings are given in the Appendix (Table 6). Internal consistency (α = .67) of the index was only approaching acceptable regions.

3.3 Data Analyses

Pearson's product-moment correlation coefficient was used to test the correlation hypothesis. Mediation and moderation analyses were conducted with standardized variables in SPSS 21 with the PROCESS software [25]. To test for significance of indirect effects, bootstrapping confidence intervals were used. Because of the high proportion of women as well as the high range of participants' age, the mediation and moderation analyses were controlled for sex, age, and, additionally, job tenure.

4 Results

As indicated by means and standard deviations of the items subsumed in the index "undefined and insecure occupational profile" (Table 5 in the Appendix), among the most salient topics was the necessity for legal amendments (stronger legal foundation for work psychologists in general, more prevention time for the evaluation of work-related psychological stressors). Furthermore, people in general and employers in particular were regarded as unaware of the competencies of work psychologists.

Respondents generally confirmed that the cooperation with occupational physicians is reasonable to them and that a more intense cooperation would be welcome (Table 6 in the Appendix). However, a considerable proportion of the respondents also confirmed cooperation problems.

Table 1 gives means, standard deviations, and correlations of the variables under investigation. While respondents exhibited rather low levels of role ambiguity, psychological wellbeing was high. Both indices (undefined and insecure occupational profile and cooperation with occupational physicians) showed moderate positive levels.

Table 1. Descriptive statistics.

	M	*SD*	1	2	3	4	5	6
1. Sex	–	–						
2. Age (years)	42.0	8.9	.23*					
3. Job tenure (years)	9.1	7.1	.34**	.60**				
4. Undefined & insecure occupational profile	3.3	0.6	.01	−.18	−.20*			
5. Role ambiguity	1.9	0.7	−.10	−.27**	−.27**	.47**		
6. Psychological wellbeing	4.4	0.9	.11	.21*	.26**	−.36**	−.45**	
7. Cooperation with occupational physicians	3.5	0.7	−.07	.09	.05	−.37**	−.25**	.20*

Note. $N = 118–122$. $^{*}p < .05$ $^{**}p < .01$

4.1 Correlates of an Undefined and Insecure Occupational Profile

All bivariate correlations were in line with expectations (Table 1). An undefined and insecure occupational profile correlated positively with role ambiguity ($r = .47$, $p < .01$), negatively with psychological wellbeing ($r = -.36$, $p < .01$, confirming Hypothesis 1), and negatively with cooperation with occupational physicians ($r = -.37$, $p < .01$). Additionally, the correlation between role ambiguity and psychological wellbeing was negative ($r = -.45$, $p < .01$) as was the relationship between role ambiguity and cooperation with occupational physicians ($r = -.25$, $p < .01$). Psychological wellbeing and cooperation with occupational physicians was positively correlated ($r = .20$, $p < .05$).

Table 2. Mediating effect of role ambiguity for the relationship between an undefined and insecure occupational profile (occup. profile) and psychological wellbeing.

Step	Variable	Path	β	*SE*	*p*	95% CI	
						LL	UL
1 (X → Y)	Occup. profile → wellbeing	c	−.33	0.09	<.01	−.51	−.15
2 (X → M)	Occup. profile → role ambiguity	a	.44	0.09	<.01	.27	.61
3 (X + M→Y)	Occup. profile → wellbeing	c′	−.19	0.10	.05	−.38	.00
	Role ambiguity → wellbeing	b	−.32	0.10	<.01	−.51	−.13
Indirect effect (X → M→Y)	Occup. profile → role ambiguity → wellbeing	a * b	−.14	0.06[a]		−.29[b]	−.04[b]

Note. *N* = 112. c = total effect, a * b = indirect effect, c′ = direct effect.
[a]Bootstrapping standard error.
[b]Bootstrapping confidence interval.

Table 3. Moderating effects of cooperation with occupational physicians (cooperation) for the relationship between an undefined and insecure occupational profile (occupational profile) and role ambiguity.

Predictor	β	*SE*	*p*	95% CI	
				LL	UL
Sex	−.19	0.20	.35	−.58	.21
Age	−.11	0.10	.29	−.31	.10
Job tenure	−.07	0.11	.50	−.29	.14
Occupational profile	.42	0.09	<.01	.24	.60
Cooperation	−.06	0.09	.51	−.23	.12
Occupational profile × cooperation	−.17	0.08	.03	−.33	−.01
R^2	.29				
F	7.20		<.01		
ΔR^2	.03				
ΔF	4.68		.03		

Note. *N* = 112.

4.2 Mediating Effect of Role Ambiguity

We found a partially mediating effect of role ambiguity on the association between an undefined and insecure occupational profile and psychological wellbeing (β = −.14, 95% CI [−.29, −.04]). Hypothesis 2 was therefore confirmed (Table 2).

4.3 Moderating Effect of Cooperation with Occupational Physicians

Cooperation with occupational physicians exerted a buffering influence on the positive effect of an undefined and insecure occupational profile on role ambiguity (β = −.17, p = .03; Table 3).

Hypothesis 3 could thus be confirmed. In addition, by combining the results of the mediation and the moderation analysis, a *moderated mediation* could be established. Conditional indirect effects of an undefined and insecure occupational profile via increased role ambiguity on reduced wellbeing at three different values of the moderator (cooperation with occupational physicians; sample mean ± 1 *SD*) are given in Table 4. As respondents rated cooperation with occupational physicians more favorably, the negative conditional indirect effect fell in magnitude. For moderator levels of one *SD* above the sample mean, the effect was no longer statistically significant (β = −.06, p > .05).

Table 4. Conditional indirect effect at different values of the moderator.

Value of the moderator	Conditional indirect effect	95% CI[a]	
		LL	UL
M − 1 *SD*	−.22	−.46	−.01
M	−.13	−.26	−.04
M + 1 *SD*	−.06	−.18	.01

Note. *N* = 112.
[a]Bootstrapping confidence intervals.

5 Discussion

The aim of this study was to examine aspects of precarious employment of work psychologists in Austria that were derived from interviews and a subsequently conducted survey study. We considered the bivariate relationships between an undefined and insecure occupational profile and role ambiguity, and, in further consequence, the respective effects on psychological well-being. Moreover, we examined a buffering effect of a well-functioning cooperation with occupational physicians on the relationship between an undefined and insecure occupational profile and role ambiguity.

Bivariate associations revealed an undefined and insecure occupational profile to correlate positively with role ambiguity and negatively with psychological wellbeing (Hypothesis 1). Hence, work psychologists who perceived an undefined and insecure occupational profile experienced more role ambiguity and less psychological wellbeing compared to work psychologists who perceived a well-defined and more secure occupational profile.

The postulated mediation effect of role ambiguity on the relationship between an undefined and insecure occupational profile and psychological wellbeing (Hypothesis 2) was also confirmed. Detrimental effects of an undefined and insecure occupational profile on psychological wellbeing were partially mediated by role ambiguity. The result suggests that work psychologists who perceived an undefined and insecure occupational profile found it difficult to identify a clear professional role, leading them to experience role ambiguity and, in consequence, less psychological wellbeing. As the mediation was partial, experiences of an undefined and insecure occupational profile still impaired wellbeing directly after controlling for the mediating influence of role ambiguity. This hints at other influences not accounted for by this study.

Lastly, the proposed buffer effect of cooperation with occupational physicians on the mediation (Hypothesis 3) was confirmed as well. The moderation analysis confirmed the helpful character of a well-functioning cooperation with occupational physicians. In particular, a well-functioning and supportive cooperation between work psychologists and occupational physicians is suitable to mitigate the emergence of role ambiguity as a consequence of a perceived undefined and insecure occupational profile. The fact that this cooperation already exerts its influence in the first stage of the mediation, thereby impeding the genesis of role ambiguity, is particularly remarkable. Therefore, cooperation with occupational physicians should be considered a vital resource for work psychologists in their professional life. Since item means hinted at certain signs of cooperation problems between work psychologists and occupational physicians, this finding becomes all the more important.

It is worth of mention that these effects were found in spite of the fact that participants reported rather low levels of role ambiguity and only moderate levels of an undefined and insecure occupational profile. A mean job tenure of nine years may partly explain these results, suggesting that a substantial portion of the sample consisted of experienced work psychologists. Hence, it is plausible to assume that the magnitude of both main and moderation effects will increase in magnitude as respondents report higher levels of an undefined and insecure occupational profile and role ambiguity, respectively—which could be expected for job entrants, for example.

5.1 Limitations

Due to the nature of the study, a compromise concerning measurement had to be made between practice-orientation (i.e., utilizing few items, generating items customized to relevant topics) and scientific standards (i.e., employing reliable and valid scales). Consequently, measurement suffered a number of shortcomings. First, we could only employ a subset of items of the original role ambiguity scale, which may have limited content validity. Second, the indices "undefined and insecure occupational profile" and "cooperation with occupational physicians" consisted of self-generated items. Since indices were composed according to qualitative results of interviews with experts in the field, they should not be expected to represent unidimensional, theoretically grounded constructs [26].

It is unclear whether the index "undefined and insecure occupational profile" and the role ambiguity scale represent two distinct constructs. Conceptually, the index comprises specific conditions unique to the work situation of work psychologists, whereas the scale abstracts from concrete work situations. A series of confirmatory factor analyses, conducted in spite of the small sample size, rather supported the notion of a two-factor solution, although fit parameters generally were unacceptable.

Causal pathways other than those proposed in this study may exist. Longitudinal data on the dynamics of the work situation and the occupational profile of work psychologists would not only help shed light on causal relationships but also capture antecedents and consequences of a developing professional profile and identity of work psychologists.

6 Conclusion

Work psychologists perceive a blurry occupational profile as an impediment to the development of their profession that elicits role ambiguity, which in turn impairs wellbeing. Cooperation with occupational physicians buffers such negative effects. Well-functioning interdisciplinary cooperation is a key factor that ensures effective interventions and is a source of social support among the professionals involved. Austrian law should more clearly define the professional role of work psychologists.

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Appendix: Item Wordings of Indices

Table 5. Items of the index *undefined and insecure occupational profile*.

Item wording	*M* (*SD*)
Form today's perspective, I would probably choose a different profession	1.91 (0.91)
Work psychologists have not established themselves on the market	3.64 (1.06)
It is difficult to develop a professional career as a work psychologist	3.58 (1.10)
A stronger legal foundation is necessary to make a living as work psychologist	4.43 (0.82)
The amount of time defined by law that may be allocated to work psychologists is insufficient for the evaluation of work-related psychological stressors	4.15 (1.02)
In order to ensure the quality of my work, I often invest additional, unpaid time	3.12 (1.31)
Most people don't know what work psychologists do	4.10 (0.91)
Most employers are not aware of the competencies of work psychologists	4.08 (0.94)
I find it difficult to explain to others what work psychologists do	1.86 (0.91)
A self-confident appearance as work psychologist would facilitate my work	2.85 (1.35)
The occupational profile of work psychologists is so vague that sometimes, I am uncertain about my own competencies	2.33 (1.10)

Note. Five-point response scale: 1 (*no, not at all*) to 5 (*yes, definitely*).

Table 6. Items of the index *cooperation with occupational physicians*.

Item wording	*M* (*SD*)
Cooperating with occupational physicians is reasonable to me	4.20 (0.82)
In my personal experience, cooperation with occupational physicians becomes difficult on a regular basis[a]	2.89 (1.11)
I would like to strengthen the cooperation with occupational physicians	3.66 (0.97)
I have the feeling that occupational physicians are not interested in a well-functioning cooperation[a]	2.94 (1.16)

Note. Five-point response scale: 1 (*no, not at all*) to 5 (*yes, definitely*).
[a]Reversed items.

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Age-Related Impairments like Reduced Hearing Capacity – A Safety Issue for the Working World?

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Abstract. According to current prognosis, an excess of age is expected for the working population. Therefore, dealing with age-related impairments of sensory functions such as hearing impairment, is a central issue. Age and age-related impairments might influence employees' performance especially in exhausting and stressful working situations. Furthermore, reduced hearing capacity bears a serious safety risk. To improve the communication especially regarding safety, communication friendly working procedures can be implemented.

A field study with white-collar workers was conducted. Audiometric data results showed that 57.9% of the participants had a slight hearing loss, 34.2% showed a mild to moderate hearing impairment. Most of the participants reported that they do strongly rely on communication at their workplace. Based on interviews and workshops difficult hearing situations were identified and procedures to prevent misunderstandings were derived. Furthermore, examples of procedures to improve the hearing environment are presented.

Keywords: Human factors · Reduced hearing capacity · Safety · Working procedures

1 Introduction

According to current prognosis, an excess of age is expected for the working population. Therefore, dealing with age-related impairments of sensory functions such as hearing impairment is a central issue. Age and age-related impairments might influence employees' performance especially in exhausting and stressful working situations. Furthermore, reduced hearing capacity bears a serious safety risk. Until now, the problem of "aged workers" and slight/mild hearing impairment and the impact for the working world has not been addressed in detail. To improve the communication especially regarding safety, communication friendly working procedures can be implemented. Therefore, it is important to develop working procedures which are as behavior-related as possible.

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1.1 Reduced Hearing Capacity

In general hearing impairment is defined as a hearing loss of 20 dB or more on at least one ear or rather the worse ear regarding the speech-relevant frequencies (0.5 kHz, 1 kHz, 2 kHz, 4 kHz) [1]. According to the WHO hearing related problems (e.g. hearing impairment or tinnitus) belong to the ten most frequent diseases in countries with middle and high income [2].

Ability to Work. One third of the participants of a large Swedish study [3] (overall number of participants = 11441) reported to suffer from difficulties with hearing (tinnitus, hearing impairment or both). Regarding the situation of employment, this study showed that 31% of the study participants were employed and 36% were non-employed. The prevalence to suffer from hearing problems increased with age and was higher in men than in women.

Furthermore, it seems that hearing impairment and early retirement may indeed have a connection: According to the National Academy of Aging Society [4] in the U.S., 18% of hearing-impaired people (age range 51 to 61 years) were retired, whereas only 12% of normal hearing people were retired at the same age.

Cognitive Performance. Beattie, Barr and Roup [5] reported that people with a slight to moderate hearing impairment show a decrease in performance regarding speech-in-noise perception with a background noise of a signal-to-noise ratio of 15 dB. This sort of background noise can be compared with the acoustic situation in an office. Furthermore, reduced hearing capacity can turn into a serious safety risk if warning and/or information signals or environmental noises cannot be heard well enough [6] or verbally given instructions are misunderstood [7].

There is indeed evidence that hearing-impaired people process cognitive information without any error, but the information processing is related to an increased effort compared with persons with normal hearing ability. To explain the difference in information processing of hearing-impaired people, McCoy et al. [8] propose the "effortfulness hypothesis" [9] which is based on the results of Rabbitt [10]. Following the "effortfulness hypothesis" a person with deficits in hearing capacity needs more cognitive resources (higher performance effort) to achieve the same perceptual performance as a normal hearing person. For hearing-impaired persons this leads to fewer available process resources compared to normal hearing persons, to encode the content.

Need for Recovery, Job Control, Job Demands. Studies about age-related differences in the "need for recovery"-concept reveal similar results concerning fatigue: older employees show more "need for recovery" than do younger employees [11, 12]. Interestingly, Nachtegaal et al. [13] showed a significant relation between „need for recovery after work "and hearing capacity, insofar that employees with poorer hearing ability reported a higher "need for recovery after work" than employees with better hearing ability.

1.2 Safety – Warning Signals, Information Signals or Environmental Noises

Following Dantscher [14] various signals can occur at workplaces. These signals range from emergency signals for evacuation, warning signals from vehicles and transportation systems to signals from machines. Partially, norms exist in which design regulations and standards for perceptibility are defined. For example, DIN EN ISO 7731 [15] defines auditory danger signals for public and work areas. Generally, three different types of danger signals can be distinguished: emergency signals in general, emergency signals for evacuation and warning signals. Following the DIN EN ISO 7731 [15] the design of these signals should be unambiguous and differ from other acoustic information. The level should reach a minimum of 65 dB(A), but should not exceed a maximum of 118 dB(A). In addition, the norm emphasizes that the signals must still be audible even if the hearing ability is limited (e.g. ear protection, hearing impairment). Furthermore, it is important to adapt the design of signals to the specific working situation in order to obtain that the signal will be heard. Dantscher [14] suggests that the use of a standard warning system, which includes clear and distinguishable signals, would simplify work. If a standard warning system would be used, workers would be able to react to warning signals in the right way, even if they change the workplace or the employer.

Reduced Hearing Capacity. Reduced hearing capacity within the working world requires special design of danger and warning signals. As mentioned before, following the DIN EN ISO 7731 [15], danger signals should be designed in a way that they are still audible even if the hearing ability is limited by using ear protection or caused by hearing impairment. The DGUV [16] affirm the importance of additive warning signals considering people with reduced hearing capacity. As for example, visual warning signals should be used in addition to the standard auditory warning signals. The DSB [17] proposes several procedures to design office elements e.g. fax-machines for hearing-impaired employees with additional blinking lights. To avoid unexpected situations, the DSB [17] suggests that hearing-impaired or deaf people should have a seat with a clear view to the door of their office.

Furthermore, considering safety risks, Lin et al. [18] found that hearing impairment might influence processes of selective attention. Moreover, Neijenhuis et al. [19] compared performance between groups of different levels of hearing impairment and found effects in selective attention at a mild hearing impairment (17.5 dB).

2 Method

2.1 Sample

The sample of this field study consisted of 38 white-collar workers. One participant did not report gender; two participants did not report age. Age ranged for the 20 women and 17 men from 26–65 years, with a mean age of 50.06 years (SD = 7.49). The 38 participants worked in two different departments of one and the same organization

(18 participants worked at department “A”, 20 participants worked at department “B”). One person did not participate in the interview due to personal reasons.

2.2 Procedure and Materials

The field study was part of the project “R-Age-III: Recovery, Age and Performance III” which is funded by the National Bank of Austria (OeNB) and consists of a field and a laboratory study. Overall, the field study was conducted over a period of 4 weeks. In the first week, the field study started with a presentation to introduce the study to the participants (approx. one hour). Following the presentation, data collection was conducted in form of the program called “Day of Hearing”. The program “Day of Hearing” included several stations on the topic “Hearing”. Overall, participants had the opportunity to visit six different stations:

1. Audiometry (pure tone audiometry was conducted and participants additionally self-assessed their hearing ability: CSS-SHI [20])
2. Interview (to identify difficult or exhausting hearing situations within the working context and find ideas on how to deal with them)
3. Occupational medicine (to clarify results of pure tone audiometry if required)
4. Psycho-acoustic phenomena (to attract participants’ interest on the hearing-topic)
5. Different Questionnaires (survey of participants’ general condition; e.g. RESTQ-Work 55/7 [21], SWE [22])
6. Cortisol (to provide a saliva-sample or hair-sample for measures of cortisol-levels) and further individual appointments (participants had the opportunity to participate in individual workplace analysis)

Both, the introduction presentation and the program of “Day of Hearing” were held separately for department “A” and department “B”. In the following two weeks participants had the opportunity, as already mentioned, to participate in individual workplace analysis. These analyses allow to collect subjective and objective information about specific working situations, where a poorer hearing ability may affect work procedures or lead to an increase in effort. Only two persons participated in these optional individual workplace analyses. Due to ethical standards of data protection, results are not reported in detail but are indeed included in the development of work procedures. In the fourth and last week of the field study, the final workshops took place (individually for department “A” and department “B”). Each workshop consisted of two different parts. In the first part of the workshop, results collected within the “Day of Hearing” and working-procedures to handle situations with challenging hearing conditions derived from the interviews, were presented and discussed. The second part of the final workshops focused on further development of work-procedures. Furthermore, information was collected, to which extend work-procedures have already been implemented in the daily working life of the participants. To do so, employees were divided into small groups to discuss and finally present their ideas on work-procedures. Furthermore, the groups of employees were invited to think about other hearing-related important domains in work life. At the end of the final workshops the field study was evaluated. Three months later, individually for department “A” and department “B” a final presentation took place to present all collected data and information of the field study.

3 Results

3.1 Audiometry

Table 1 shows the distribution of participants to the three different hearing groups. In contrast to criteria of the European Commission and WHO the classification of hearing groups was implemented using audiometric data of participants' worse ear because even hearing impairment on one ear can lead to problems in working situations. Due to this fact, hearing impairment on one ear can be relevant from the viewpoint of occupational psychology and of strain in work life.

The results show that 34.2% of the participants are mild to moderate hearing-impaired. Regarding 57.9% of participants, at least a hearing related problem relevant to occupational psychology can be shown.

Table 1. Distribution of participants to hearing groups.

Hearing group	Frequency
Normal hearing	3 (7.9%)
Slight/mild hearing impairment ($\geq$ 15 dB on min. 2 frequencies of 0.5, 1, 2, 4 kHz)	22 (57.9%)
Mild to moderate hearing impairment ($\geq$ 20 dB; avg. 0.5, 1, 2, 4 kHz)	13 (34.2%)
Total	38 (100%)

3.2 Importance of Communication at the Workplace

Most of the participants (51.4%) reported that they rely on communication at their workplace to a very great extent (see Fig. 1).

3.3 Difficult Hearing Situations

65.7% of the participants answered the interview question "Do you know situations, which are difficult or exhausting referring to 'hearing'? "with "yes" (see Fig. 2).

The participants named the following difficult hearing situations:

- **Conference calls:** visual information is missing; necessity to distinguish between several voices
- **Connection difficulties/poor mobile signal and poor mobile phone reception:** concerning mobile phone in the company building as well as on route
- **Ventilation unit:** permanent background noise
- **Environmental noise:** traffic noise (street and railway station) close by
- **Office situations:** background noise when several employees talk on the phone at the same time; customer service
- **Meetings/Discussions:** necessity to distinguish between several voices
- **Language barriers:** technical jargon; misunderstandings.

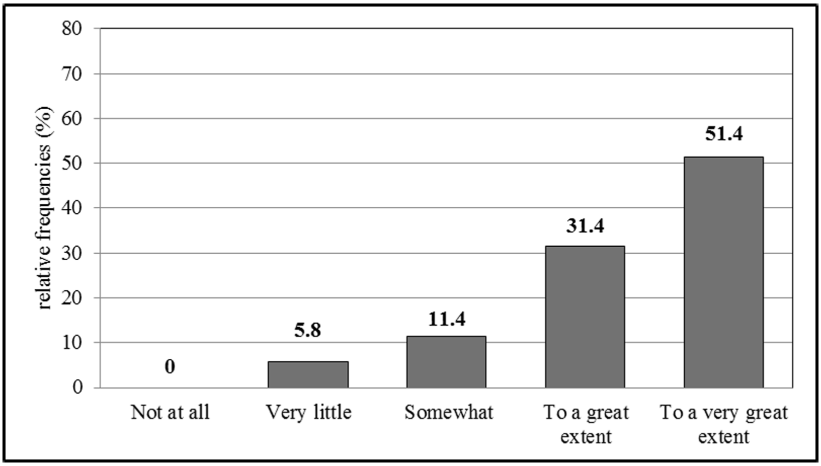

Fig. 1. Importance of communication at the workplace.

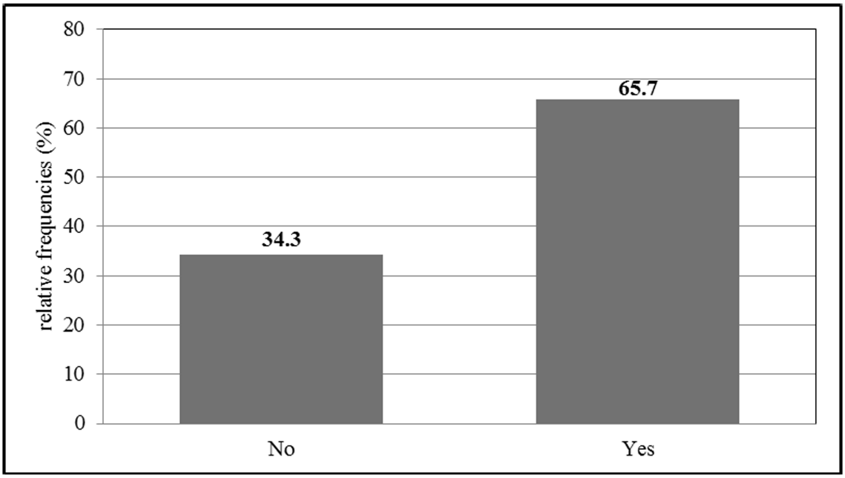

Fig. 2. Difficult hearing situations.

4 Derivation of Procedures – Some Examples

Based on interviews and workshops, difficult hearing situations were identified and procedures to prevent misunderstandings were derived. Examples of behavior-related "coping"-procedures are:

- **Face-to-Face communication** especially to make eye-contact with the dialog-partner
- **Use of media** like emails instead of using the telephone to communicate important messages

- **Flexible working hours:** Coordination of tasks which require a quiet environment with working times of colleagues in the same office; more flexible core times
- **Organization of the working week:** Plan to do complex tasks on days, when most of the other office-colleagues are not in the office (e.g. on route, in meetings, on sales force)
- **Fixed-line connection/landline phones instead of mobile phones:** To avoid connection difficulties on mobile phones resp. poor mobile signal in the company building, it would be useful to install landline phones for employees who spend most of their working time in the office
- **Information Mode:** If connection difficulties occur, ask the person to write an email
- **Interpreter:** To avoid language barriers it can be helpful to invite the concerning person to come to the office with an interpreter (e.g. family member etc.…)
- **Explain difficulties:** If connection difficulties or language barriers occur, explain the problem and try to find a common solution
- **Communication rules:** Agree on signals, signs and gestures so that colleagues know, if a certain task requires silence (e.g. raise or wave one's hand, etc.)
- **Volume adjustment:** Adjust the volume of the phone to the individual optimum
- **Headset:** Considering longer conversations on the telephone using a headset can be more comfortable
- **Spatial situation:** Define a special room where employees can go to and work if certain work tasks need silence or high concentration
- **Background noise:** Try to reduce background noise to a minimum as for example turn off the radio when concentration is needed or use agreed signal to show the colleagues if a task requires silence (see also communication rules).

5 Discussion

First, the empirical data have shown that many employees are at least slightly hearing-impaired. These results indicate that hearing impairment is an important age-related impairment that should be considered especially in the light of expectations for an aging of the working population. The results of our study are in line with data of the WHO. Following the WHO hearing related problems belong to the ten most frequent diseases in countries with middle and high income [2].

The importance of the ability to hear and understand information will be even more emphasized by the results that show that 83% of the participants rely on communication at their workplace to a (very) great extent. It would be easy to assume that an uncorrected hearing impairment might lead to problems and in the worst case to safety risks in their working life.

Two-thirds of the participants reported difficult hearing situations at their workplace. Based on these results and the results of two workshops, procedures for persons with reduced hearing capacity in different working environments have been developed in a behavior-related manner. The derivation of procedures within our field study highlights the importance of the involvement of employees in their "normal" work places. From our point of view, without this approach, a behavior-related derivation of procedures that reflect problems in employees' every day work life would not have been possible.

Overall, the field study could attract employees' interest on the topic "Hearing" and represents an important first step on the integration of the topic "Hearing" in the working field. To receive a more comprehensive view on this important subject, further research should be carried out regarding hearing impairment in the working world. It might be also interesting to analyze different working areas and occupational fields.

Future Prospects. Currently, an experimental study is being conducted to find the procedures with highest effect sizes.

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Managing Tacit Knowledge in Safety Critical Systems

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Abstract. Knowledge is in the heads of people. Managing knowledge is more than maintaining data bases, but making sure, that relevant knowledge is transferred from head to head. This is especially difficult regarding tacit knowledge on both, individual and collective level. In this applied research project, two methods aiming at improving an organization's knowledge management were developed: (a) A method for evaluating existing knowledge management processes from a comprehensive point of view providing concrete measures for improvement and (b) a method especially referring to the elicitation of team specific collective tacit knowledge aiming at facilitating cooperation awareness and triggering individual as well as joint learning. Both methods were developed in close cooperation with industrial partners and pilot tested. They delivered valuable insights for improvements.

Keywords: Knowledge management · Evaluation · Knowledge elicitation · Individual tacit knowledge · Collective tacit knowledge · Patterns of team cooperation

1 Introduction

In safety critical systems, managing knowledge is becoming more and more crucial. This is due to an increasing complexity of the systems as well as due to an increasing division of labor. Both make cooperation of experts more and more demanding. Although many organizations have knowledge management tools in place, the exchange of knowledge often does not work in a sufficient manner. This is especially true regarding tacit knowledge.

Normally knowledge management focuses on documenting knowledge in written electronical form. However, effective knowledge management is more than that. It makes sure that knowledge is interpersonally transferred. Since knowledge is not "a piece of paper" but a human property, knowledge management is not simply a question of documentation, but subject of a transfer process that makes sure, that knowledge is transferred "from heads to heads". This process involves three phases: Knowledge elicitation, knowledge documentation, and – in the core of the process – actual use of knowledge.

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In close cooperation with Swiss nuclear power plants (NPP) a method was developed that supports both, (a) the evaluation of an organization's existing knowledge management processes as well as (b) the elicitation of tacit knowledge.

The evaluation method is generic. Based on state of art insights regarding promoters and barriers of knowledge management it supports organizations in identifying strengths and weaknesses in its knowledge transfer processes. The scope of this evaluation is deliberately broad. It does not focus on the process only, but also on framework conditions such as the procedure of its implementation or the culture it is embedded in.

Whereas normally processes and instruments for managing explicit knowledge are in place, the interpersonal exchange of tacit knowledge is much less systematically supported. This is especially true for collective tacit knowledge. It was therefore an objective of this research to develop a respective method. The method considers collective tacit knowledge as distributed tacit knowledge regarding patterns of cooperating in work teams. These patterns emerge over time in teams with a stable personnel composition and allow for effective cooperation without explicit coordination. In a perfectly functioning team this collective tacit knowledge involves a high compatibility of (mainly unconscious) mutual expectations regarding cooperation. Such it allows for a highly synergetic acting. However, if the mutual expectations do not fit, disruptions in cooperation are likely to occur, reducing team performance. As the mutual expectations are tacit such disruptions may especially develop under the condition of fluctuation in team composition.

Following, the two developed methods for evaluating knowledge management processes and for eliciting tacit knowledge are described in more details.

2 Evaluation of Knowledge Management Processes

2.1 Subject of Evaluation

The evaluation refers to all three phases of knowledge management. This makes sure that knowledge management is not reduced to maintaining databases (i.e. documentation of information) but considers the knowledge management process in a comprehensive manner, including both, knowledge elicitation as well as interpersonal exchange of knowledge (i.e. actual use of knowledge), the latter of which is the core of knowledge management.

Phase 1: The Elicitation of Relevant Knowledge. Several questions have to be answered in a first phase: What type of knowledge should be transferred (tacit or explicit knowledge, collective or individual knowledge)? Which contents are relevant? Who are the experts in the organization possessing this relevant knowledge? And, finally, which methods, tools or techniques are suitable to elicit this type and content of knowledge? Therefore, the aim of this first phase is to make specific knowledge available for knowledge transfer.

Phase 2: The Documentation of Knowledge. In a second phase, the elicited knowledge has to be documented in an appropriate manner. Form and structure of this documentation have to be compatible with the specific type of knowledge and have to support the actual use of the elicited knowledge. While checklists or user manuals are suitable to document explicit factual knowledge they are presumably not appropriate for the documentation of tacit knowledge, e.g. an expert's operating experiences. To address that kind of knowledge, other forms or formats, like videos, photos or prints, are necessary.

Phase 3: The Actual Use of Knowledge. The third phase contains the actual transfer of the elicited and documented knowledge from one person to the other. The organization should support the interpersonal exchange of knowledge and it has to ensure that this transfer actually leads to a gain of knowledge. Quality management of the contents and processes of the knowledge management is only one critical issue here.

2.2 Promotors and Barriers of Knowledge Management

Several individual, technical as well as organizational factors do influence knowledge transfer processes in an organization [1–3]. On the one hand, they can promote and support knowledge transfer, on the other hand, negative values of these factors can also turn to barriers regarding the processes of knowledge management (cf. Table 1 for examples of promoters and barriers). High values of the promoting factors and low values of the impairing barriers are optimal for an effective knowledge transfer.

Table 1. Promoters and barriers of knowledge transfer processes (examples).

Level	Promoters	Barriers
Individual	Positive perceived benefit Curiosity Willingness and ability to learn Trust into security of employment Trust in colleagues …	Negative experiences Fear of knowledge expropriation Consciousness regarding value of experiences Competition among colleagues …
Technical	Positive user experience with tools …	Inappropriate usability of tools …
Organizational	Supportive learning culture Commitment of management Participation …	Blaming culture Intolerance regarding divergent points of view …

2.3 Evaluation Method for Knowledge Management

The evaluation method applies an explanatory sequential design as suggested by Creswell and Plano Clark [4]. This design belongs to the group of "Mixed Method Designs". These designs involve the collection, analysis, and integration of quantitative and qualitative data in a single or multiphase study. Accordingly, the evaluation starts with collecting and analyzing quantitative data in order to identify hot spots, followed by an in-depth qualitative analysis of these hot spots.

The quantitative analysis is designed as a generic approach supporting the development of a questionnaire referring to promoters and barriers of knowledge management as known from research (cf. Table 1). This questionnaire identifies and evaluates these promoters and barriers on each level – individual, technical and organizational – and in each phase of knowledge transfer – elicitation, documentation and actual use of knowledge. Furthermore, the questionnaire addresses aspects of the implementation process of knowledge management tools in the organization and their actual use. Thereby, knowledge management relevant hot spots (e.g. problems) are identified.

In-depth data analysis is supported by guidelines for interviews. On the one hand, these interviews should be conducted in order to deepen and to substantiate questionnaire's findings regarding problems in the knowledge transfer processes. On the other hand, ideas and suggestions for improvements can be developed in a participatory way based on the interviews.

Additionally, the method supports the interpretation of the data and the derivation of specific measures for optimizing the organization's knowledge management processes. Improvements should address reductions of the barriers and a support of the promoters – on each stage and in each phase of knowledge transfer processes. A periodic monitoring of the measures' effects ensures continuous improvement of knowledge transfer in the organization.

3 Elicitation of Tacit Knowledge

The increasing complexity and division of labor in safety critical systems make cooperation of experts more and more needed, but also demanding. Thus, the cooperation of experts has become a crucial success factor in such systems. Within this cooperation, collective tacit knowledge evolves. Collective tacit knowledge evolves from the cooperation of different experts and hence from the interaction of different individuals' tacit knowledge when aiming to achieve a common objective. When the same people work together over a long time period, team-specific patterns of cooperation (routines) are creeping in [5]. Over time, team members individually and often unconsciously develop specific expectations regarding the cooperation within the team. According to the distributed situation awareness theory [6], the compatibility of the team members' mutual expectations are paramount for successful cooperation and, thus, are key elements of collective tacit knowledge. A lack of systematic maintenance of collective tacit knowledge may cause disruptions in cooperation (e.g. unintentional misunderstandings), especially in case of staff fluctuation.

In close cooperation with Swiss NPPs a method for systematic elicitation of tacit knowledge was developed and pilot tested. Elicitation means according to the SECI-Model of Nonaka and Takeuchi [7] to grasp and to document experience-based knowledge of experts – that is tacit and therefore difficult to articulate – in a systematic way that enables further use. The method addresses both, individual as well as collective tacit knowledge.

The method involves a pre- as well as a post-job workshop and a systematic exchange during job execution (cf. Fig. 1). The three phases build on one another thereby following an approach of stepwise deepening. The method's aims are to support (a) the stepwise elicitation of individual and collective tacit knowledge, (b) the development of individual as well as collective learnings derived from the cooperation experienced in the team, and (c) the derivation of concrete measures to promote the interpersonal knowledge exchange as well as to improve the cooperation in the team.

The pre-job workshop is a workshop with all members of a team the working process of which is subject of the method's application. The aims are (a) the first-time elicitation of individual as well as collective tacit knowledge and (b) the documentation

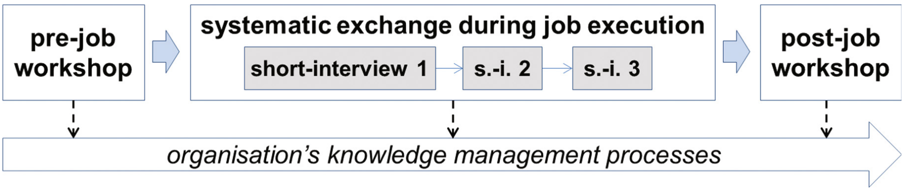

Fig. 1. The three steps of the knowledge elicitation method: Pre-job workshop, short-interviews during job execution, post-job workshop.

of the elicited knowledge using specific template cards. The workshop's methodology is based on group discussions [8] as well as on the principles of storytelling [9], group storytelling [10], causal mapping [11], and the self-q-technique [12]. According to these methods, tacit knowledge can be elicited by generating story-like narratives as well as by a stepwise question-based deepening approach.

In the first workshop-part individual tacit knowledge is elicited by discussing a fictitious but realistic scenario (a short-term absence of an experienced team member and its replacement with an unexperienced colleague) facilitated by reflection-promoting questions. In the second workshop-part the team's collective tacit knowledge is elicited. In detail, implicit mutual expectations as well as uncertainties regarding the cooperation in the team are elicited using question-guided group discussions. The elicited expectations as well as uncertainties are documented in the form of messages between team members using specific template cards.

The systematic exchange during job execution contains an exchange and answering of the messages developed in the pre-job workshop. Therefore, three short interviews (10–15 min) with each team member are conducted. The aims of the systematic exchange and the short interviews are (a) to recognize and to deal with incompatible expectations among team members, (b) to resolve uncertainties regarding upcoming cooperation, and (c) to develop and document individual learnings regarding past cooperation in the team. The interviews are based on interview guidelines.

The post-job workshop builds on the elaborated content in the first two phases (elicited knowledge, exchanged and answered messages). The aims are (a) to derive individual and collective learnings from the elicited knowledge as well as from the cooperation experienced in the working process and (b) to define concrete measures to promote the interpersonal knowledge exchange as well as to improve the cooperation within the team. Therefore, in a moderated group discussion along specific questions, collective as well as individual learnings are elicited and documented. Based on these learnings concrete (individual as well as collective) measures to promote the knowledge exchange as well as to improve the cooperation within the team are derived. These measures are to be implemented in the next teams' working processes.

The testing has shown that the method supports the elicitation and systematic cultivation of individual as well as collective tacit knowledge in a moderated process. Thereby, it supports (a) the exchange of valuable tacit knowledge among team members, (b) the cooperation awareness between team members, and (c) the early recognition of incompatible mutual expectations as well as uncertainties regarding the cooperation in the team. This enables taking proactive measures to avoid disruptions in cooperation, especially in case of staff fluctuation. Furthermore, the method delivers valuable tips to be included into the organization's knowledge management process.

4 Conclusions

Knowledge management is far more than maintaining a data base. This is because knowledge is not primarily "a piece of paper" but an expertise growing in the humans' heads over years of experience. In its core knowledge management refers to the deliberately managed process of transferring such expertise "from heads to heads". This involves three phases: Eliciting relevant knowledge from heads, documenting this knowledge in an appropriate manner, and making use of the knowledge, i.e. making sure both, it is transferred to other person and it is of use for their work. Implementing these three phases is especially difficult for tacit knowledge be it on individual as well as on collective level.

To support knowledge management, this research addressed gaps in existing knowledge management practices. Two main gaps were identified. First, there are a lot of knowledge management processes and instruments in place (e.g. wikis, databases, standard operation procedures, focus group meetings, mentoring systems, etc.). However, these systems are often likely to underperform. Second, especially referring tacit knowledge there is little systematic support. On the level of individual tacit knowledge transfer often depends on personal style; e.g. some seniors strongly support juniors by taking time to share their experiences; other seniors hardly talk or document something. On the level of collective tacit knowledge instruments of knowledge transfer are largely lacking.

Regarding the performance of knowledge management processes and instruments an evaluation method was developed taking a broad view; i.e. considering influencing factors on individual, technical, as well as organizational level. This includes individual motivation as well as the respective instruments' usability, the culture respective processes are embedded in or the approach of their implementation. The method follows a two steps design. First, a quantitative analysis allows for identifying strengths and weaknesses in the given knowledge processes and instruments. Such, hot spots for improvement are identified. Second, in-depth qualitative analysis on the base of semi-structured interviews allow for detail analysis and development of concrete measures for improvement. The method was pilot tested and proved to deliver valuable insight for the respective company.

Regarding knowledge elicitation, a structured process for teams was developed that focuses on both, individual as well as collective tacit knowledge. The latter deliberately makes explicit team specific patterns of cooperation that – more or less consciously – creeped in over time of working together in the same team constellation. Such, that method makes implicit mutual expectations explicit and hence avoids disruptions in cooperation. The method furthermore supports a systematic derivation of individual as well as joint learnings. The method was also pilot tested. It did not only deliver valuable insights but was also greatly adopted by the participants.

Both methods did positively support the industrial partners' knowledge management. However, future research is required especially regarding collective tacit knowledge. By focusing on team specific implicit cooperation patterns and synergic acting of team members it is possible to conceptualize collective tacit knowledge, going beyond the mere sum of individuals' tacit knowledge. Nevertheless, a more differentiated understanding of distributed tacit knowledge as a property of a social system is an endeavor worth to work on.

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Advancing Organisational Health and Safety Management: Are We Learning the Right Lessons?

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Abstract. The twenty-first century has seen many changes, together with improvements in health and safety performance in some sectors. These improvements are testimony that the combined effects of regulatory enforcement, proactive leadership and investments in safety technology are bringing in some tangible benefits overall. However; organisational accidents still occur, raising the question of whether key learnings from previous disasters are used for informing organisational health and safety management practices. This paper, based on an analysis of findings from the Mocando Well Blowout and Fukushima Disasters, seeks to explore this very research question. This paper first discusses key factors identified in reports of the above disasters, followed by an introduction to organisational learning. Safety through organisational learning is proposed as a method, and a number of suggestions made for advancing research and practice in safety management through these approaches in the general industry.

Keywords: Organisation accidents · Organisational learning · Safety through organisational learning · Organisational safety management

1 Twenty-First Century Safety Management Challenges

Organizations in the twenty-first century are being challenged on a number of fronts. Some of those identified below arise from technological changes:

- rapid pace of changes in technology occurring at such speeds that engineering techniques required to cope with their associated risks are unable to keep up [1],
- new hazards and risks being created from a combination of dependency on information systems, incorrect or loss of information, digitalisation, and new forms work organisations [1, 2],
- increasing complexity and coupling of organisational systems, with systems being designed with significant potential interactions among the different components that cannot be fully planned, understood, anticipated or guarded against [1, 3],
- more complex relationships between humans and automation, arising from humans sharing control of automated decision-making platforms resulting in new types of errors [1, 4],
- the changing perspectives on accident/incident causation from events, sequences, systems, systemic and functional resonance [2, 5].

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One could argues these are likely to impact more on some parts of the industry, including those that are very large, operate with very high levels of technology and operate in multiple sectors. Other challenges arise from changes to organisation and work and impact on general, mainstream and contemporary industries. Some of these, for example, include:

- decline in manufacturing industries and rise in knowledge-based and service industries [6, 7],
- changes in the techniques, technologies and skills employed at work, resulting in increases in occupations requiring either very high levels of skills or relatively few skills [6, 8],
- changes in labour market, resulting in increased sub-contracting, part-time, self-employment and temporary employments [7, 9]
- more companies are operating globally, resulting in increased pricing and product competition [9, 10]
- product and service demands are shifting rapidly amidst pressure for higher quality and customized products [11, 12], and
- an aging and increasingly diverse workforce and tightening labour markets [11].

Both challenges impact the way organizations manage health and safety, as they not only need to deal with existing but also emergent hazards and risks, and amidst a range of uncertain environments and contexts.

If one used some set of statistics, they would argue (perhaps quite rightly), that much progress has been made in improving safety performance in many countries. For example, between 2010 and 2015, work-related fatalities decreased from 228 to 194 in Australia [13], with similar trends observed from New Zealand (77 to 43) [14] and Great Britain (175 to 142) [15]. These improvements can be attributed to a combination of increased enforcement by safety regulators, proactive approaches by safety leaders in organisations, adoption of improved safety technology, and changes to reporting and analysis systems. However, many practitioners would also argue that much more that needs to be done because organisational accidents impacting on the lives of many people continue to occur in both developed and developing countries. In the next section two organisational accidents which have not only made news in recent years, but continue to interest many researchers, practitioners and policy makers are briefly reviewed. A number of other, similar accidents are also briefly summarised.

2 Mocando Well Blowout and Nuclear Disasters

The Mocando well blowout and Fukushima disasters are two notable organisational accidents in recent years that have caught the attention of many researchers, policy makers and the media. A recent search of *Google Scholar* for these topics generated about 2700 results (0.06 s) and 37,100 results (0.07 s) respectively.

2.1 The Macondo Well Blowout

The Macondo well blowout, explosion and fire on the *Deepwater Horizon* offshore drilling rig on April 20, 2010; resulted in 11 workers being killed and another 16 seriously injured, with an estimated 5 million barrels of hydrocarbons released into the Gulf of Mexico over a period of three months after the disaster [16, 17]. A number of factors have been suggested to contribute to this disaster, including

i. a very small margin of safety between the fracture mud weight and the mud weight necessary to avoid flow into the well;
ii. great difference in density between the two types of cements used in the pumping sequence of the cement casing of the walls when preparing the well for temporary abandonment,
iii. incorrect interpretations of the negative pressure tests when assessing the integrity of the cement casing,
iv. continued displacement of drilling mud with seawater following the incorrect interpretation,
v. inability of sensors to detect and control hydrocarbon following previous failure of the cement and mechanical barriers,
vi. the emergency blowout preventer (BOP) and blind shear ram (BSR) systems failing to disconnect the oil rig from the well,
vii. design, testing, operation and maintenance of BOP not being consistent with high-reliability, fail-safe design,
viii. misplaced trust by government and industry leaders on the ability of BOP to act as a fail-safe mechanism,
ix. complex structure and division of expertise in the design, operations and maintenance of the overall operations,
x. inadequate management processes,
xi. not using a comprehensive systems approach for managing the safety aspects of the operations,
xii. limited safety training provided to operations personnel, and
xiii. lack of a strong safety culture [16–18].

2.2 Fukushima Nuclear Disaster

The Fukushima nuclear disaster occurred on March 11, 2011 has been acknowledged as the second most serious one in the nuclear industry after Three Mile Island [19]. A major earthquake and tsunami, which resulted in the death of three employees, preceded the disaster [20]. By March 2015 over 15,000 were killed, over 6000 injured and 2500 people were still reported as missing [21]. In addition, about 150,000 people were evacuated, 173 workers exposed to more than 100 millisieverts of radiation while dealing with the disaster, and some 1 8000 km^2 of land in Fukushima Prefecture contaminated by an accumulative dose greater than 5 millisieverts per year [20]. Some of the main factors which has been suggested to have contributed to this disaster include:

i. inadequate corporate governance by key stakeholders,
ii. inadequate risk assessments and lack of safeguards against known threats,
iii. inadequate levels of knowledge, training, and equipment inspection related to severe accidents,
iv. inadequate emergency response training and preparedness,
v. ineffective crisis management system due to ambiguities in roles and responsibilities between regulators and responsible agencies,
vi. negligence and failure by regulators' to implement adequate measures against a nuclear disaster,
vii. inadequate regulatory oversight by regulators and government,
viii. a lip service policy of 'safety first', and
ix. a failure to follow international best practice standards [22–24].

While these disasters occurred over 5 to 6 years ago, have things improved, both in the above, or other similar sectors of the industry? Table 1 summarises examples of a number of other organisational accidents which have occurred between 2011 and 2016.

Table 1. Examples of organisational accidents [25–27]

Date	Location	Industry	Type	Deaths and [injuries]
Oct 2016	Queensland, Australia	Amusement Park	Faulty water ride	4
April 2013	Texas, USA	Fertilizers	Explosion	15 [160]
Nov 2012	Dhaka, Bangladesh	Garment manufacturing	Fire	112
Sep 2012	Karachi, Pakistan	Garment manufacturing	Fire	289
Sep 2012	Yegoryevsk, Russia	Garment manufacturing	Fire	14
Sep 2012	Lahore, Pakistan	Shoe manufacturing	Fire	25
Sep 2012	Sivakasi, India	Fireworks manufacturing	Explosion	37 [60]
Aug 2012	Paraguana, Venezuela	Refinery	Explosion	48 [151]
May 2012	Rayong, Thailand	Synthetic rubber manufacturing	Explosion	12 [100]
Nov 2011	Shandong, China	Chemical manufacturing	Explosion	14

The occurrence of these, and other similar organisational accidents that have occurred elsewhere suggests that many organisations continue to fail to learn from events of the past.

3 A Failure to Learn the Right Lessons

The argument that organisations fail to learn is nothing new as shown by previous organisational disasters such as the *Challenger* [28], *Titanic* [29], Sago Coal Mine [30]; as well with Macondo [31] and Fukushima [24]. What is repeatedly found in reports following these types of disasters is that there were always failures to learn from earlier and minor events which preceded the disasters. What we also need to ask, is *whether organisations are learning the right lessons* from these disasters? This is an important question to consider for both academic and pragmatic reasons.

3.1 Organisational Learning

Organisational learning (OL) was originally conceptualized by Argyris [32] and gained prominence in the 1990s. The high level of interest has been linked with the publication of *The Fifth Discipline* [33]. Since then it has received much attention in studies involving, for example sustainability [34] and culture [35, 36]. While many studies have acknowledge that OL is an important, a clear definition of what this actually is does not exist [37]. Some of its key characteristics have been suggested to include adaptations [33, 38]; innovations, culture, process and routines [37, 39].

3.2 Organisational Learning and Safety

According to the OL literature, analysing and learning from events is important for preventing future events. One suggested method for doing this involves safety through organisation learning (SOL), initially developed for the German nuclear industry trialed in the chemical industry [40]. The authors have suggested it facilitated OL by supporting the process of analysing events, standardising how these analysis were conducted, mobilising multidisciplinary expertise and knowledge, and creativity in the analysis. A search of the published literature, however, suggests there has been little published on SOL from mainstream industries; hence there is an opportunity for empirical research on OL and safety. In order to advance such research, there are a number of questions that can be posed. For example:

i. *which type of events, incidents and/or occurrences should be analysed*? One common practice in organisations is to concentrate on those which have led a fatality, serious or disabling injury. This focus on failures alone creates an impediment to OL because successful events such as near-misses, dangerous occurrences and other 'successes' are missed entirely [41]. Such events represent the flip side of failures and occur more often than failures, so it made more sense to understand why and how these occurred [42],

ii. *what should be learnt from the events, incidents and/or occurrences and analysis?* There is always a sequence of events preceding, during and following an occurrence. Organisational disasters are usually complex events and involve some preconditions, triggers, the event (or series of events) itself, an outcome, recovery and learning [43], so it is important that the correct information is collected, coded, classified and described [41]. Because the final outcome of OL is successful adaptation, it then holds that such learning should aim at knowing and knowledge on:

a. what happened,
b. what to do,
c. what to look, and
d. what to expect in the future [42],

iii. *when should the learning take place?* The main focus of attention following organisational accidents and major disasters is around clean up, suppression of information flow to the media and regulators. Efforts of (any) learning are usually left after some levels of inquiry or investigations have been completed. However, underlying OL is the presence of a system for detecting, notifying and addressing unexpected events which arise within the organisation, including those which contravene operational practices, or are contrary to it's norms and values [44]. In order to promote OL, therefore, methods and tools need to be in place to enable an organisation acquire, analyse and enable changes to be made in order to improve performance on a continuous basis,

iv. *who should learn?* In most instances, where there is any reference to any learning from incidents, the ultimate recipients are the operators themselves, as part of behaviour and error control! OL, however, requires that members from all levels are involved [45, 46].

4 Conclusion

Organisations in the twenty-first century continue to experience a number of challenges, and these can impact the way they manage health and safety. Amidst these challenges improvements are being made in terms of reduced number of workplace fatalities. However, because organisational disasters continue to occur, it is apparent that many organisations are failing to learn the right lessons for advancing safety management from the experiences of industries outside their sector. Organisational learning offers an opportunity to provide some redress, and this paper proposes a set of four key questions that can be examined using SOL as a way of advancing research and practice in organisational safety management. Future works will seek to explore, examine and measure some of these important research questions.

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Anomaly in Safety Management: Is It Constantly Possible to Make Safety Compatible with Economy?

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Abstract. Although it is clear that we must satisfy both economy and safety, we sometimes place more emphasis on economy than safety, which leads to a critical disaster or crash. The reason must be identified for the further enhancement of safety. This study explored why one cannot satisfy both economy and safety. We attempted to explain the reason using the collapse model of proper balance between safety and economy (efficiency) induced by the following cognitive biases: (i) mental accounting, (ii) loss aversion, and (iii) discount of safety. The measure or remedy of this collapse of the proper balance between safety and economy (efficiency) was proposed as (a) disclosure system, (b) commitment approach to safety, and (c) mechanism design.

Keywords: Anomaly in safety management · Irrational behavior · Efficiency · Mental accounting · Loss aversion · Discount of safety

1 Introduction

Ideally and rationally, it goes without saying that we should make safety compatible with economy. However, based on the analysis of cases of past disasters or crashes, it is doubtful whether it is possible to reconcile economy and safety especially when the related organization cannot help aiming at higher efficiency to maintain and sustain organizational and managerial activities and protect employees. There are many cases that led to a critical disaster due to the lack in the balance between safety and economy and optimistically and unconsciously regard safety as less important than efficiency (economy).

The JOC criticality disaster or Fukushima Daiichi disaster is included in such cases, and such disasters or crashes are repeated in spite of some preventive measures taken cautiously. In the JOC criticality disaster, the workers violated the job rule predetermined by Science and Technology Agency, Japan (limitation of mass and limitation of shape during the manufacturing of uranium solution) in order to improve efficiency of uranium solution process [1]. The workers optimistically and irrationally altered the manufacturing process six times. This was also done not abruptly but gradually. During this impermissible alteration, the safety of uranium manufacturing was made light of. In other words, the JOC could not make safety compatible with efficiency (economy).

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In the Fukushima Daiichi nuclear power plant (NPP) disaster, only the problems and deficiencies in Fukushima Daiichi NPP have been paid attention to by many researchers and mass medium. Although the comparison of Fukushima Daiichi and Fukushima Daini NPP is seldom conducted, it is important and useful to carry out a comparative study between two NPPs. The operators in Fukushima Daini NPP managed to suppress the outbreak of a disaster and eventually a significant consequence. It is said that the reason why Fukushima Daini NPP did not suffer from a severe damage like Fukushima Daiichi is the height of sea embankment and the mechanism of cooling system (water-cooling or air-cooling system). The unconscious and optimistic biases must have worked when investing money for enhancing the safety of Fukushima Daiichi NPP. TEPCO (Tokyo Electric Company) also did not attempt to reconcile safety and economy. The compatibility of safety with economy is a very important issue in safety management. In this manner, the collapse of balance between safety and efficiency (economy) can sometime become a critical cause of disaster.

The aim of this paper was to discuss why one cannot satisfy both economy and safety. An attempt was made to explain the collapse model of proper balance between safety and economy (efficiency) induced by the following cognitive biases: (i) mental accounting, (ii) loss aversion, and (iii) discount of safety. The measure or remedy of this collapse of the proper balance between safety and economy (efficiency) was proposed as (a) disclosure system, (b) commitment to safety, and (c) mechanism design that makes use of judgment of Solomon by which king Solomon judged which of two women was a true (genuine) mother of a baby.

2 Reasons Why Anomaly in Safety Management Occurs

It is well-understood that safety should be more important than economy (profit or efficiency) as far as we always behave rationally. In spite of this understanding, we encounter a situation under which profit or efficiency is paid more and more attention than safety. Thaler [2–4] and Shiller [5] pointed out anomaly in economics, and showed that we do not always behave rationally as Econ does. Such a situation leading to irrational behavior in safety sometimes becomes a trigger of critical crashes, collisions, or disasters [1, 6–13]. This study discussed why one cannot satisfy both economy and safety. An attempt was made to explain the reason why the collapse of proper balance between safety and economy (efficiency) is induced by means of the following cognitive biases: (i) mental accounting, (ii) loss aversion, and (iii) discount of safety.

2.1 Mental Accounting

According to Thaler [2–4], we tend to behave using multiple mental accounts for different kinds of resources. For example, we use different monthly budgets (mental accounting) for grocery shopping and eating out at restaurants. Therefore, we constrain one kind of purchase when its budget has run out of its mental accounting while we do not constrain the other kind of purchase when it does not run out of its mental accounting, although both consumptions come from the same monthly income. Similarly, we tend to spend less money at the market when paying with cash than with credit cards, even though both cash and credit card come from the same economic resource.

Decisions on purchase or consumption are affected by the mental account that comes to mind when deciding whether to consume their resources. Consumption of a fixed amount of money such as $100 of one's own money is felt more painful when that consumption is from a smaller rather than a larger mental account.

In this manner, mental accounting represents our irrational behavior that divides our money into different mental accountings, although rational behavior never classifies our money into different mental accounts. Therefore, it can be assumed that there are mainly two different mental accounts, that is, mental accounting for making a profit and that for investing money for maintaining safety in an organizational or managerial activity. Such an irrational behavior (separation of investment or money into two different mental accounts) can be a trigger of imbalanced state of more importance of economy or efficiency than safety. In other word, it is likely that we unconsciously place more importance on the efficiency or profit than on the safety due to mental accounting, although we know that the safety and the efficiency or profit must be simultaneously satisfied.

2.2 Loss Aversion

Loss aversion [8] is well-known as our irrational behavior. We generally feel more disappointed when we loose, for example, $100 than when we gain the same amount. Therefore, we tend to be averse to economic or monetary loss especially when we are constantly under an economically tough situation, which collapses the balance between economy (profit or efficiency) and safety [10]. In March 1977, a Boeing 747 KLM Flight 4805 left Amsterdam and was bound for Las Palmas Airport on the Canary Islands. A terrorist bomb explosion occurred at a flower shop in Las Palmas Airport, and so, the flight, along with a few others, was diverted to Tenerife Airport. After landing at the airport, the flight waited for clearance from the air traffic controller (ATC) to take off, but because of reduced visibility due to fog at the airport, the clearance was delayed. The captain, however, decided to take off without permission from the ATC, and he turned the throttles to full power on the foggy runway. Unfortunately, a Pan Am 747 plane was parked across the runway as the KLM Flight 4805 approached it at take-off speed. Although the captain attempted to avoid a collision by trying to take off as early as possible, the underside of KLM flight's fuselage ripped through the Pan Am plane, and the KLM plane burst into a fiery explosion. All crew and passengers of the KLM plane and many passengers of the Pan Am plane lost their lives.

Loss aversion strongly contributed to the KLM Flight 4805 crash. In this case, the losses for the captain of the flight include a reduced mandated rest period due to the flight delay, the cost of accommodating the passengers at a hotel until the situation improves and a series of consequences of the flight delay, such as stress imposed on the captain and a blot on the captain's reputation of being punctual. The complicated interaction of these factors probably triggered and escalated the captain's feeling of loss aversion. The more significance we attach to potential loss, the more loss aversive we tend to be. The captain must have been preoccupied with the urge to reach the destination as early as possible and must have lost his sense of safety, resulting in his decision to take off without clearance from the ATC.

2.3 Safety Discount

Discount of safety is also regarded as a cause of imbalance of safety and economy. As well as the time discount of economic (monetary) items, it is pointed out that the value of safety is also discounted [14]. The authors' experimental data on the discount phenomenon of safety are shown in Fig. 1. To get this data, the participants were required to evaluate the distance to jump across (perceived risk) RS as a function of the time to detour E when the length of precipice or gutter is equal to 1 m. As shown in Fig. 1, the safety data can be modeled by a hyperbolic discount curve as in economic phenomenon.

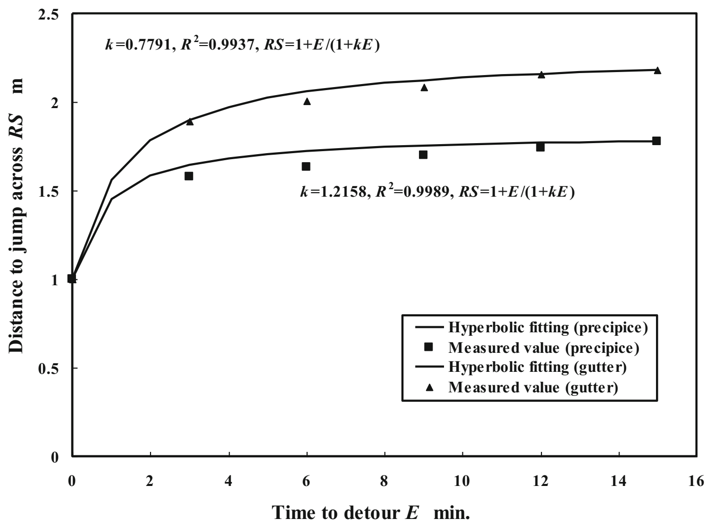

Fig. 1. Discount phenomenon of safety.

The safety discount rate was higher when the perceived risk was lower (gutter) than when the perceived risk was higher (precipice). This suggests that we tend to discount safety to a larger extent when the perceived risk on safety is lower than when the perceived risk on safety is higher. This shows that magnitude effect [15] holds even in the discount phenomenon of safety. Magnitude effect suggests that the lower perceived risk is, the more safety is discounted, which might induce the imbalance between safety and efficiency. The imbalance between safety and economy makes us perceive the risk on safety lower and becomes a trigger to pursuit economy by sacrificing safety.

Irrational mental accounting tends to produce different accounts for profit and safety pursuit. Under a managerially difficult situation, we unconsciously tend to place more emphasis on a profit mental account, and avoid investing money on safety. We sometimes get loss aversive, in particular, in pursuit of profit. This, together with mental accounting, further makes us place less emphasis on safety, feel less risky even if the risk is higher than that we actually feel, and discount safety. This eventually causes the imbalance between efficiency and safety. In the next section, it is discussed how such cognitive biases that make us unable to make safety compatible with profit or economy.

3 Discussion: How Anomaly in Safety Management Should Be Overcome

In Sect. 2, we inferred that the collapse of the proper balance between safety and economy (efficiency) was caused mainly by three irrational factors (cognitive biases), that is, mental accounting, loss aversion, and discount of safety.

The remedy of this collapse of the proper balance between safety and economy (efficiency) was proposed as follows: (a) disclosure system, (b) commitment to safety, and (c) mechanism design (that makes use of judgment of Solomon by which king Solomon judged which of two women was a true (genuine) mother of a baby).

3.1 Disclosure System

It is generally believed that disclosure system reduces dishonesty or unethical behavior, and eventually the violation of safety rules or regulations. Loewenstein et al. [16] discussed the effects of regulations that require public disclosure of information. These requirements are most sensibly imposed in situations characterized by misaligned incentives and asymmetry of information between, for example, a regulation officer and safety management staff at workplace. The disclosure of information must be effectively carried out for the purpose of resolving the imbalance between safety and efficiency (economy). The full-disclosure principle [17], for example, can prevent corporations from guaranteeing even relatively low quality products caused by asymmetry of information. Here, asymmetry comes from the fact that producers or manufacturers know more than consumers about their products.

It has been discussed how different psychological factors complicate the appearance of unethical behavior or violation of rules or regulations. Bounded awareness and biased assessments of revelation probability of unethical behavior or violation on the part of information recipients can significantly diminish the intended effectiveness of disclosure requirements. These factors also become a trigger of cognitive biases [10, 18, 19]. In many cases, without reducing the asymmetry of information, disclosure does not function satisfactory between workers or safety management staff at workplaces and the safety regulation staff or management of corporation. The asymmetry of information between the workers and the safety regulation staff or management prevents both groups from sharing important information necessary for maintaining safety. Although the disclosure of information is necessary to resolve the asymmetry of information between providers and recipients, this does not necessarily works for the resolution of asymmetry of information. Bateson [20] showed that cues of being watched enhance cooperation in a real-world setting. Inferring from this study, the feeling of being watched at all times must be effective for preventing the imbalance between safety and efficiency as well as frequent disclosure of information on safety.

The effective and frequent disclosure of information, in particular, the safety and economic or managerial investment must be conducted to resolve the asymmetry of information between the workers at workplace and the safety regulation or management staff at workplace. With such a disclosure system, it would have been possible to prevent JOC criticality disaster [1]. In this disaster, the workers violated the job rule (limitation of mass and limitation of shape during the manufacturing of uranium solution) in order to improve efficiency of uranium solution process. The information of this alteration process was never shared between the regulation staff and the workers. The workers optimistically, irrationally, and gradually altered the manufacturing process six times without being watched by the safety regulation staff. JOC could not make safety compatible with efficiency (economy).

3.2 Commitment and Emotional Approach to Safety

Frank [17] proposed that commitment makes one's behavior or act to something effective, and it was shown that emotion plays an important role in enhancing commitment. Damasio [21, 22] found that emotion is essential for the rational decision making. Commitment to safety with emotion must work for the prevention of imbalance between safety and economy (or efficiency). Frank [17] also states that no amount of punishment and reward seems sufficient to induce people to behave according to a rule without emotional conditionality.

Homer's Odysseus faced the situation to sail past dangerous reefs where sirens lay. Because Odysseus realized that once he confronted with earshot of sirens' cry, he would be irresistibly sailed to his doom on the reefs, he was able to foresee the wrong behavior and come up with effective commitment to instruct his crew to strap him tightly to the mast and not release him until they had sailed safely past. This commitment was not possible without emotional conditionality. Similar commitment is seen, for example, in whole-life insurance policies which impose substantial penalties on withdrawal before retirement. The proper balance between the intelligence and the emotion must be essential for the effective work of commitment.

Frank [17] pointed out the efficacy of the selfless act for the achievement of cooperation, and offered the need to further refine the decision theory used in traditional economics whereby materialist motives of self-interest are ascribed to the average person weighing costs and benefits for every economic action. In such a situation, safety problems are neglected unconsciously, and it becomes impossible to make safety compatible with economy. Therefore, the commitment to safety for prudential cooperation must be effective. In the commitment to safety, as mentioned above, it is important to clarify the role of the emotions in facilitating socially efficient interactions and proper decision making that does not induce the imbalance between safety and economy.

It is not so easy to learn the advantage of passing up the small and early reward (temporally profit) in favor of the large and later reward (everlasting safety) as shown in Sect. 2.3. We tend to discount more largely to the small and early reward (short-term managerial profit) than to the large and later reward (safety at present and in the future). It tends that we unconsciously place more emphasis on a profit mental account than a safety maintenance account, in particular, under a managerially difficult situation. We sometimes get loss aversive, in particular, in pursuit of profit. This further makes us feel less risky even if the risk is higher than that we actually perceive, and thus we discount safety. This eventually causes the imbalance between efficiency and safety.

To cope with such a situation, commitment approach to safety with emotional conditionality would be one promising measure to prevent such willingness not to passing up the small and early reward.

3.3 Mechanism Design

The Judgment of Solomon refers to a story in which King Solomon ruled between two women both claiming to be the mother of a baby by tricking them into revealing their true feelings. It has become an archetypal example of game-theoretical or mechanism design argument of an impartial and fair judgment displaying wisdom in decision making.

It is assumed that a government must confirm the safety of nuclear power plant (NPP) and decide whether the construction of NPP should be promoted or not. First of all, the following symbols are defined. m_{no}: there are many safety concerns in the construction of NPP (NPP is not safe). m_{NPP}: there are no problems in the construction of NPP. It is assumed that the government must judge which argument of Group A or Group B is correct and reliable. The following events are defined.

a. The argument of Group A is correct.
b. The argument of Group B is correct.
c. Both Group A and Group B are not correct, and cannot be relied upon.

Table 1. Basic data for construction of nuclear power plant.

Group B / Group A	m_{no}	m_{NPP}
m_{no}	*a*	*c*
m_{NPP}	*c*	*b*

Rank	1st	2nd	3rd
Group A	*a*	*b*	*c*
Group B	*b*	*c*	*a*

2-stage evaluation

Government cannot identify a correct Group

As shown in Table 1, the government cannot know which argument is correct as it is. Therefore, the mechanism design approach [23, 24] was applied to identify a genuinely correct group. Group A and Group B know which insistence is correct. It is also assumed that the insistence of Group A is genuinely correct. The value or satisfaction accepted by a government is determined as follows.

V_H: correctly insistent Group
V_L: incorrectly insistent Group, where $V_H > V_L$

.

Group A and Group B can be described as follows.

Group A (Safety: Assurance ⇒ Safety: Insistence): This group genuinely assure safety (Safety: Assurance) ⇒ This group insists in public that their proposal is safe (Safety: Insistence).

Group B (Safety: Non-assurance ⇒ Safety: Insistence): This group falsely assure safety in spite of their proposal not assuring safety (Safety: Non-assurance) ⇒ This group insists in public that their proposal is safe (Safety: Insistence).

Group A genuinely assures safety, and insists that their policy can surely attain safety. Group B, on the surface, insists that their policy attains safety, although the group knows that their policy cannot actually assure safety. In order to know which group is genuinely correct, the following two-stage mechanism design is effective.

If the insistence of both groups does not coincide, it is assumed that Safety: Assurance ⇒ Safety: Insistence (Group A) and Safety: Non-assurance ⇒ Safety: Insistence (Group B) is punished by x and y, respectively. If Group A is correct, $V_H > y > V_L$. Group B cannot help choosing m_{no} as shown in Fig. 2 to suppress and minimize his or her loss. Such a mechanism design enables us to choose a correct alternative. With such a mechanism, it may be actually possible to make safety compatible with economy, because

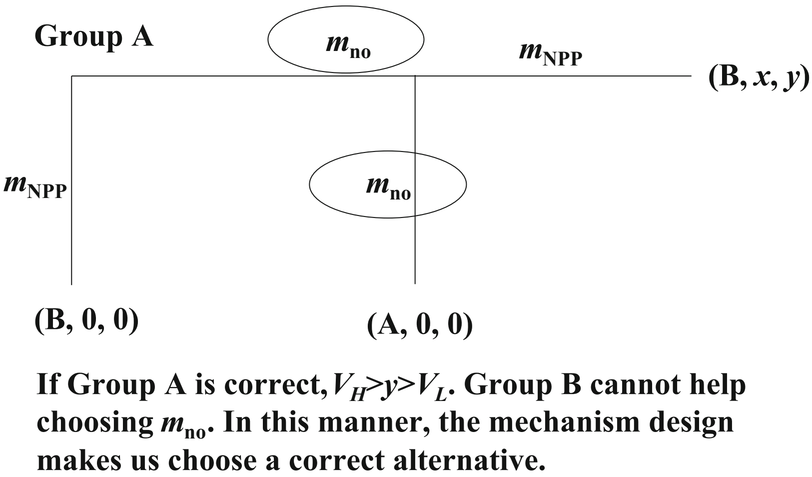

Fig. 2. Mechanism of judgment of truth of Group A (against NPP) and B (for NPP) on NPP promotion by government.

Group B must in advance pay y for the assurance of safety to promote the construction of NPP with its own responsibility so that they don't get trapped into loss aversion bias and too much emphasize on efficiency. It is possible that such a mechanism design can avoid the cognitive biases of discount of safety and mental accounting that becomes a trigger of not willing to invest money for the assurance of safety.

The effective disclosure and the commitment approach to safety with emotional conditionality would work satisfactory if a mechanism design approach to promote such measures is effectively used. In this manner, one can make safety compatible with efficiency or profit.

4 Conclusions

The aim of this paper was to discuss why one cannot satisfy both economy and safety. The results can be summarized as follows.

We inferred that the collapse of the proper balance between safety and economy (efficiency) was caused mainly by three irrational factors, that is, mental accounting, loss aversion, and safety discount. The remedy of this collapse of the proper balance between safety and economy (efficiency) was proposed as (a) disclosure system, (b) mechanism design, and (c) commitment of safety.

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Needs and Opportunities for Applying Voluntary Occupational Health and Safety Management Systems in the High-Hazard U.S. Dairy Production Industry

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Abstract. The U.S. dairy industry has had consistently high rates of occupational injuries. Occupational health and safety management systems (OHSMSs) have potential to reduce injury rates, but lacking a regulatory mandate for such a system, it is uncertain if U.S. dairy farmers will adopt an OHSMS. Needs assessment interviews were developed and validated to assess the attitudes, experiences, and interests of dairy workers and managers about OHSMS approaches to worker safety. Non-parametric statistical methods were applied to determine whether there were differences between the mean responses of workers and managers and whether their expressed attitudes and interests were significantly strong in favor or against OHSMSs. Thirty-two dairy workers and four managers from four farms completed the interviews. There were no significant differences in attitudes or interests between dairy workers and management. Most of the attitudes and interests were strongly favorable of OHSMS approaches, suggesting that dairy farmers may be willing to adopt an OHSMS voluntarily.

Keywords: OHSMS · Injury and illness prevention program · Occupational safety and health program · Farm safety · Needs assessment

1 Introduction

Occupational injuries and illnesses are common in the U.S. dairy production industry. Between 2006 and 2015, the rate of injuries per 100 full-time workers averaged 5.7, ranging from 3.9 to 7.3 [1]. This was higher than the average rates during the same 10-year span across all U.S. employment sectors and in the broader agriculture sector specifically, which were 3.6 and 5.1, respectively [1]. Common hazards among dairy farm workers include being crushed by cattle, contact with heavy machinery, ergonomic stresses among workers who milk cows or handle calves, and respiratory exposures [2].

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The causes of these events and conditions are multifactorial including direct, indirect, and systemic risk factors. Important direct risk factors include insufficient training, poor ergonomic design of dairy equipment, and environmental exposures [3, 4]. A largely immigrant, migrant, non-English speaking workforce, many of whom have a fear or distrust of government authorities are some important indirect risk factors for occupational injury and illness among dairy farm workers [5]. Furthermore, the dairy industry has historically been neglected by regulators responsible for occupational health and safety (OHS), with fewer than 700 federal regulatory inspections having occurred on dairies between 2003 and 2012 despite there being more than 45,000 U.S. dairy farms in operation [6]. Systemic risk factors include a lack of training, lack of standard operating procedures and poor leadership [3, 7].

Given the objectionably high rates of injuries and wide range of occupational morbidities and risk factors, comprehensive risk management methods are needed to protect workers employed on U.S. dairy farms. Occupational health and safety management systems (OHSMSs) have shown promise as a means to reduce overall injury rates. Studies have demonstrated that voluntary OHSMSs in the U.S. can reduce hazards, reduce costs, and reduce injuries in general [8, 9]. Unfortunately, little has been published on whether these results are applicable to the dairy industry. An Australian study published in 2011 evaluated how well different agriculture industries had adopted OHSMS-like regulations [10]. The study revealed that dairy was one of the highest performing agricultural industries (ranked third out of seven), but that fewer than half had adopted a farm health and safety plan (39%) or provided introductory safety training for farm workers (43%) [10]. In the U.S., it has been reported that pork producers were willing to adopt OHSMSs, particularly when checklists and guides are included [11]. In a 2016 study of U.S. dairy farms that had participated in a free government health and safety consultation program, farms with higher levels of OHSMS programming were generally associated with lower rates of injuries and illnesses [12]. However, the study was correlational and observational in nature and examined only coincident injury rates and OHSMS programming [12]. To date, no OHSMS intervention studies have been published in the dairy industry, although a replication study found similar associations in the poultry production industry [13].

One potentially important barrier to an OHSMS intervention program for dairies is the acceptability of such an intervention for dairy farmers and farm workers. In the U.S., there is no federal government mandate for businesses to adopt an OHSMS, and few states require any type of systemic approach to worker safety. California is the most noteworthy exception, having enacted an "Injury and Illness Prevention Program" (IIPP) rule for most employers since 1991 [14]. However, employers with fewer than 20 employees are exempted from most of the IIPP requirements and most U.S. dairy farms employ fewer than 20 people [14]. Thus, OHSMS adoption would be a voluntary measure for most U.S. dairies, 95% of whom employ fewer than 20 workers [15].

The study presented here was conceived to ascertain whether U.S. dairy farmers and farm workers would be interested and supportive of adopting a voluntary OHSMS. The objectives of this work were to measure the attitudes toward, experiences with, and interest in, systemic OHSMS approaches among U.S. dairy workers and employers. The needs assessment results should provide evidence for or against the development of an OHSMS intervention to reduce occupational injuries and illnesses among dairy farm workers.

2 Methods

2.1 Interview Instruments

A needs assessment interview instrument was developed to assess the attitudes, experiences, and interests of dairy workers and dairy managers/owners as they relate to systemic approaches to occupational health and safety. The worker instrument consisted of eight questions on attitudes that used a four-point forced-choice scale, eight experience questions that used yes or no answers, and seven more four-point scale questions about how interested dairy workers were in participating in OHSMS-related activities. The scaled responses to interview questions about attitudes and interests were worded as 0 = strongly disagree or very disinterested; 1 = slightly disagree or somewhat disinterested; 2 = slightly agree or somewhat interested; and 4 = strongly agree or very interested, respectively.

A second interview instrument was developed for dairy owners and managers. This instrument had the same number of questions on attitudes and experiences, but had six additional questions assessing interests. The additional questions focused on management aspects of systematic occupational health and safety, such as demonstrating support for safety, getting workers involved in safety, and contractor safety.

Both interview instruments were assessed for content validity using an expert opinion panel. This panel of national expert reviewers included researchers experienced with dairy health and safety, OHSMSs, and dairy management. Each one of these experts provided their opinions on the interview instruments and offered suggestions for improvement. In addition, we had a dairy owner and a dairy worker review and evaluate their relevant instruments. This preliminary validation (face, consensual, and content validity) is consistent with methods used to develop interview instruments for medical services needs assessments [16], and education research assessments [17]. Neither the criterion validity nor the reliability of the interview instruments was assessed.

Both interview instruments were written in English. They were then translated into Spanish by an independent third party. A Spanish-speaking former dairy worker and a bi-lingual dairy management researcher verified the accuracy of the translated interview instruments.

2.2 Subject Recruitment and Interview Process

A convenience sample of four dairy farms in a western U.S. state that had participated in a local university extension program on dairy management in 2014 was targeted for this study. The sample represented a variety of dairy farm sizes that included small (100 to 999 head of cattle), medium (1,000 to 2,499 head), and large (2,500 + head, according to National Agriculture Statistics Service classifications), and a variety of processes (organic and non-organic) [18]. A bi-lingual member of the research team visited each farm and interviewed all of the available workers and either the farm owner (for smaller farms) or the farm general manager (for larger farms). Dairy farm workers and owners/managers were approached using an Institutional Review Board Approved recruitment script. All participants were interviewed in either English or Spanish depending on which language was preferred. Resource limitations prevented additional dairy farm visits within the study period. The subject recruitment and interview process was conducted according to methods approved by the Colorado State University Institutional Review Board.

2.3 Data Analysis

The goals of the data analyses in this study were (1) to examine if there were any significant differences in the opinions of dairy workers and owners/managers; and (2) to determine if the opinions of dairy farm workers and management were convincingly strong for or against a number of aspects related to an OHSMS.

The first goal was assessed using a two-sided Wilcoxon Rank-Sum Test for concordant items on the worker and owner/manager interview instruments. The null hypothesis was that there was no difference between the mean score of either group for a particular question.

The second goal was assessed by analyzing the responses to attitude and interest questions from workers and owners/managers using a one-sided, one-sample sign test. The null hypothesis was set to a value of 3 out of 4 for each question included in the analysis. If the median response was significantly greater than three for a question, then that was considered evidence of a significantly strong opinion in favor of that particular construct of an OHSMS. If the mean response was not significantly strong, then a second one-sample sign test was conducted using a null of two and a less-than alternative. This would be considered strong evidence against a particular interview item.

Non-parametric statistics were employed to address both goals because the interview items cannot be considered interval or ratio scale, which precluded the use of other analyses. Minitab 17 Statistical Software (State College, PA, U.S.A.) was used to perform all analyses in this study.

3 Results

3.1 Participant Demographics

Thirty-two farm workers and four owners/managers participated in the interviews from four dairy farms. The farms included a large organic dairy and a large non-organic dairy, a medium-sized non-organic dairy, and a small non-organic dairy farm. No one refused to participate in the study.

Of the 32 dairy workers who participated in this study, 23 were male (72%) and all of the workers who reported their country of origin (25/32, 78%) were born outside of the U.S. The most common country of origin reported was Mexico (15/25 reporting, 60%) followed by Guatemala and El Salvador (3/25 reporting, 12% each); Ukraine (2/25 reporting, 8%); and Peru and China (1/25 reporting, 4% each). All of the seven workers who did not report a country of origin spoke Spanish, resulting in a total of 29 out of 32 dairy worker respondents who completed the interviews in Spanish (91%). The mean age of the worker participants was 34.6 years (range 19 to 64 years) among the 24 who reported their age.

Of the four dairy owners/managers who participated, one was an owner and three were farm general managers. Three of the four owners/managers (75%) completed their interviews in English. Only two of the four owners/managers (50%) provided an age. The average reported age was 33.5 years, ranging from 30 to 37 years.

3.2 Interview Results

Attitudes Toward Systematic OHS. In the first portion of the interviews, dairy farm workers and owners/managers were asked how strongly they agreed or disagreed with seven statements about systematic approaches to OHS. The individual questions and the responses of worker and owner/manager participants are summarized in Table 1.

During the instrument validation process, an eighth item was added to this section. The results of this question are presented separately because it did not specifically gauge an attitude toward systematic OHS. The mean response to the eighth statement "I know where to find information about workplace safety issues", was 2.8 (range 1 to 4) for both workers and owners/managers.

Table 1. Attitudes about systematic occupational health and safety among dairy farm workers (n = 32) and dairy owners/managers (n = 4).

Attitude statement	Worker reponses[a] mean (Range)	Management reponses[a] mean (Range)
1. Safety is better addressed at the organization level rather than at the individual level	3.7 (2 to 4)	3.8 (3 to 4)
2. Safer environments for workers are also safer environments for livestock	3.7 (2 to 4)	4.0 (4 to 4)
3. Injury prevention is everyone's responsibility on a dairy farm rather than just one person's	3.7 (1 to 4)	3.8 (3 to 4)
4. There is a relationship between worker safety and work quality	3.7 (2 to 4)	3.5 (3 to 4)
5. There is a relationship between worker safety and worker productivity	3.5 (2 to 4)	3.3 (3 to 4)
6. Worker safety needs improvement on my farm	3.2 (1 to 4)	3.0 (2 to 4)
7. Worker safety represents a significant challenge to dairy farming	3.2 (1 to 4)	3.3 (3 to 4)

[a]Participants rated each statement either 1 (strongly disagree), 2 (somewhat disagree), 3 (somewhat agree), or 4 (strongly agree)

Experiences with Systematic OHS. In the second portion of the interviews, participants were asked if they had experience with any of eight OHSMS-related behaviors in the previous year. Among the 32 dairy worker participants, 17 (53%) indicated they had performed preventive maintenance on farm equipment; 20 (63%) had found and fixed workplace safety hazards; 6 (19%) had participated in farm safety inspections;

23 (72%) had received safety training; 16 (50%) had reported safety concerns to their supervisor; 17 (53%) had discussed safety concerns with other workers; 10 (31%) had suffered a workplace injury; and 12 (38%) had reported a workplace injury to their supervisor.

Among the four participating dairy owners/managers, 2 (50%) indicated they had attended training or conferences on worker safety; 4 (100%) had identified and controlled workplace safety hazards; 3 (75%) had conducted farm safety inspections; 2 (50%) had provided farm safety training to workers; 2 (50%) had documented a workplace injury; 4 (100%) had communicated safety concerns to workers; 3 (75%) had discussed farm safety concerns with colleagues and/or other farmers; and 2 (50%) had created farm safety goals for their farm.

Interest in OHSMS Approaches. In the final part of the interviews, dairy farm workers and owners/managers were asked how interested they were in participating in (for workers) or learning more about (for owners/managers) several OHSMS-related activities. Dairy workers were asked seven questions in this section and management participants were asked 12. The individual activities and participant responses are summarized in Table 2.

Table 2. Interest in occupational health and safety management system approaches among dairy farm workers (n = 32) and dairy owners/managers (n = 4).

Interest activity	Worker reponses[a] mean (Range)	Management reponses[a] mean (Range)
1. Creating a safety policy for your farm	3.3 (2 to 4)	4.0 (4 to 4)
2. Creating safety goals and objectives for your farm	3.2 (1 to 4)	4.0 (4 to 4)
3. Identifying unsafe work conditions on your farm	3.7 (3 to 4)	3.5 (3 to 4)
4. Correcting workplace safety hazards on your farm	3.6 (2 to 4)	4.0 (4 to 4)
5. Worker safety training and education	3.9 (2 to 4)	4.0 (4 to 4)
6. Investigating the causes of workplace injuries	3.2 (2 to 4)	3.5 (3 to 4)
7. Emergency response and preparedness	3.6 (2 to 4)	3.5 (3 to 4)
8. Demonstrating to workers that you support worker safety	Not applicable	3.8 (3 to 4)
9. Getting workers to participate in farm safety	Not applicable	3.5 (3 to 4)
10. Safety documentation and recordkeeping	Not applicable	3.5 (3 to 4)
11. Contractor safety	Not applicable	3.3 (2 to 4)
12. Occupational Safety and Health Administration (OSHA) worker safety regulations	Not applicable	3.5 (2 to 4)

[a]Participants rated each statement either 1 (very disinterested), 2 (somewhat disinterested), 3 (somewhat interested), or 4 (very interested)

An additional question was added to this section for owners/managers during the instrument validation process. Owners/managers only were asked, "How concerned are you about OSHA regulations and inspections." Possible responses ranged from 1 = not at all concerned, 2 = a little concerned, 3 = somewhat concerned, and 4 = very concerned. The mean rating of management participants was 3.3 out of 4 (range 2 to 4).

3.3 Comparison Between Workers and Owners/Managers

There were no significant differences between the ratings of dairy workers and dairy owners/managers on any of the concordant attitude and interest interview questions, as assessed using a Wilcoxon Rank-Sum test. However, one of the attitude statements and four of the interest questions could not be assessed using this method because there was no variability in the owner/manager responses. The results of these comparative analyses are provided in Tables 3 and 4.

Table 3. Results of a comparison between dairy worker (n = 32) and dairy owner/manager (n = 4) responses to systematic occupational health and safety statements

Statement	Difference in median rating	Significance level[a]
1. Safety is better addressed at the organization level rather than at the individual level	0.0	p = 1.00
2. Safer environments for workers are also safer environments for livestock	0.0	N/A[b]
3. Injury prevention is everyone's responsibility on a dairy farm rather than just one person's	0.0	p = 1.00
4. There is a relationship between worker safety and work quality	0.5	p = 0.29
5. There is a relationship between worker safety and worker productivity	1.0	p = 0.47
6. Worker safety needs improvement on my farm	0.0	p = 0.57
7. Worker safety represents a significant challenge to dairy farming	0.0	p = 1.00
8. I know where to find information about workplace safety issues	0.0	p = 0.78

[a]As measured using a Wilcoxon Rank-Sum test.
[b]Not applicable; there was no variability in the manger responses for this item.

Table 4. Results of a comparison between dairy worker (n = 32) and dairy owner/manager (n = 4) responses to occupational health and safety management system approaches

Interest activity	Difference in median rating	Significance level[a]
1. Creating a safety policy for your farm	0.0	N/A[b]
2. Creating safety goals and objectives for your farm	0.5	N/A[b]
3. Identifying unsafe work conditions on your farm	0.5	p = 0.48
4. Correcting workplace safety hazards on your farm	0.0	N/A[b]
5. Worker safety training and education	0.0	N/A[b]
6. Investigating the causes of workplace injuries	0.5	p = 0.54
7. Emergency response and preparedness	0.0	p = 0.76

[a]As measured using a Wilcoxon Rank-Sum test.
[b]Not applicable; there was no variability in the manger responses for this item.

3.4 Strength of Opinions

The mean dairy worker rating on six of the eight attitude statements was significantly higher than a three out of four ($p < 0.05$ for all six statements). The two statements which were not were "Worker safety needs improvement on my farm", (mean 3.2, $p = 0.057$) and "I know where to find information about workplace safety issues", (mean 2.8, p 0.74). These two statement ratings were also not significantly less than a two out of four.

Similarly, the mean dairy worker ratings for five of the seven interest activities were significantly above a three out of four ($p < 0.05$). The two interest activities that were not rated significantly above a three were "creating safety goals and objectives for your farm" (mean 3.2, $p = 0.09$), and "investigating the cause of a workplace injury" (mean 3.2, $p = 0.20$). Neither of the statements was rated significantly below a two out of four.

None of the management attitude statement mean ratings were significantly positive (greater than 3) or negative (less than 2), with a range of $p = 0.063$ to $p = 0.750$.

4 Discussion

Mean responses to all of the attitude statements among dairy farm workers and management were positive, and worker ratings on six out of the eight statements were significantly strong (above a three out of four). These findings indicate that participants had a generally favorable opinion of systematic approaches to OHS. Further, there were no significant differences between the average attitude ratings of dairy workers and owners/managers, suggesting there are similarities between these groups in terms of desire for systematic OHS approaches. This is encouraging because OHSMS regulations are lacking in the U.S. and OHS regulatory attention in the industry has been generally sparse. Thus, any adoption of an OHSMS in the dairy industry would need to be voluntary.

Participants from both groups also indicated that there was a lack of knowledge in terms of being able to find available OHS information, as evidenced by it rating the lowest out of all of the statements and being the only statement with a mean rating below a three out of four. Providing information to dairy workers and management may therefore be a good first step when considering potential OHSMS interventions in the U.S. dairy industry.

Responses to the experience questions among workers and owners/managers provide insight into OHSMS-related activities already being accomplished on dairy farms, which could make OHSMS interventions more accessible. Half or more of the dairy worker participants had performed preventive maintenance, fixed hazards, reported safety concerns to a supervisor, and received safety training. Notably, over 30% of worker respondents reported being injured on the job in the previous year. While attempting to assess the injury experience of dairy workers was not a focus of this study, the high proportion is consistent with findings from a previous study that found a 16.6% per year injury rate among 600 dairy workers, which was substantially higher than U.S. Bureau of Labor Statistics reports over that same time period and the result is indicative of the need for OHS related interventions for dairy farm workers [15]. It was a surprise to see that more workers reported an injury to their supervisor (38%) than had experienced an injury (30%). This discrepancy may be due to how the interview question was worded. The question about reporting an injury did not specify a worker's own injury, and therefore the result may have included workers reporting injuries to themselves and their fellow workers.

Dairy owners/managers also reported experience with a number of OHSMS-related activities. Fifty percent or more participants indicated they had experience with each one of the eight experience questions in the previous year. These worker and management experiences can be used to tailor an acceptable OHSMS intervention for dairy farms that builds upon practices that may already be in place.

Worker and management participants also indicated an overall strong interest in participating in (for workers) or learning more about (for owners/managers) OHSMS approaches to OHS. All interest activities had a mean response above a three out of four, and five out of the seven worker rating averages were significantly above a three, indicating that they were very interested in participating in most of the OHSMS-related activities. Again, a high degree of agreement between workers and management was indicated by the lack of any significant differences between the interest ratings of the two groups. However, a lack of variability among the owner/manager responses limited this analysis to only three of the seven corresponding interest questions.

4.1 Limitations and Strengths

Several important limitations should be considered when interpreting the results of this study. Conducting interviews on only four farms in a single U.S. state largely limits the degree to which the participants can be considered representative of the larger U.S. dairy industry population. In addition, because farms were selected based on their managements' participation in a local university extension program focused on dairy management, these farms may be different from those that did not participate in these programs, especially with regard to owner/manager beliefs and opinions. The small sample size also limited our ability to analyze similarities and differences between workers and management on some items, and to statistically assess the strength of opinions in the management group. In five separate instances, there was too little variability in the management responses to allow for a rank-based non-parametric comparison with the worker responses. Further, the small sample size increased the likelihood that random chance could explain any observed findings. The lack of quantitative psychrometric data on the criterion validity and reliability of the interview instruments is another important limitation of this study. While this was a small needs assessment study that did not require any additional instrument analyses, these should be considered before the instruments are adopted for other research in other contexts.

There were also several strengths of this study. In particular, the needs assessment included the opinions of both dairy workers and management. This is critical because management support and employee participation are commonly considered to be important determinants of OHSMS success [19, 20]. Another strength was that the interviews were conducted in Spanish and English to match the preferred language of most participants. The interview instruments were also validated by national experts on dairy management, OHSMS, and agricultural OHS research. Finally, this is the first study to document the attitudes, experiences, and interests of U.S. dairy personnel with regard to a comprehensive risk management approach to OHS.

5 Conclusion

There are four main conclusions that can be drawn from this study. First, the overall attitudes of participant dairy workers and owner managers toward systematic OHS were generally positive. Second, dairy workers and owners/managers who participated in this study had experience with a number of OHSMS-related activities. Third, dairy workers and owners/managers were generally interested in participating in and learning more about OHSMS approaches to OHS. And lastly, there were no significant differences between the opinions of dairy workers and dairy owners/managers who participated in this study.

Although the limitations of this study prevent extrapolation of our findings to the dairy industry as a whole, the results provide additional evidence that OHSMS interventions may be appropriate to attempt to reduce the rate of injuries and illnesses among U.S. dairy workers. This study should help to inform the design of intervention studies for dairy farms by highlighting areas where some dairy personnel have experience with and interests in OHSMS-related activities and areas where there is potential agreement between dairy workers and managers. Further research is needed to determine if the opinions of our participants are similar to those in the broader U.S. dairy industry.

U.S. dairy producers who employ fewer than 250 workers and are interested in establishing an OHSMS can request free, confidential assistance through the OSHA On-Site Consultation Program. Larger producers interested in an OHSMS can find consultant services through the national organizations of OHS professionals.

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Factors Which Affect Construction Safety in Different Types of Construction Work

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Abstract. During the process of construction, accidents may happen in different ways. In this paper, we firstly review the literature related to the asymmetric information on construction site. Next, the author will report some interviews and questionnaires used to study the causes of construction accidents that happen in different types of buildings (such as building sites, bridges and tunnels). The author will draw a conclusion at the end of the paper to summarize the causes of construction accidents in different kinds of buildings.

Keywords: Asymmetric information · Construction safety · Hong kong

1 Introduction

Construction safety is a critical issue in the process of construction. Guo, Yu, and Skitmore [4] suggested that the construction safety issue has become more popular in recent years because of the high accident and death rates. The Labour Department of the Hong Kong Government's '*Summary of Occupational Safety and Health Statistics of 1st Three Quarters of 2016'* has been published and shows that industrial accidents in the construction industry increased by 0.7% in the 1st three quarters of 2016 compared with the 1st three quarters of 2015 (Table 1).

There is a critical need to collect data on the construction industry in detail to study the major risk elements in detail in order to provide some suggestions and make improvements. In this paper, we will report the causes of construction accidents in different types of buildings and find out the major risk elements for construction accidents. Firstly, the author will present a literature review of the asymmetric information held by different stakeholders in construction sites. Secondly, the causes of accidents in various types of building structures (including skyscrapers, bridges, tunnels, etc.) will be determined from the feedback from surveys and interviews. The author summarizes the main causes of accidents on construction sites. Thirdly, the author makes some suggestions according to the data collected by the questionnaire and interviews. Last but not least, the author will draw a conclusion on the research.

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Table 1. Comparison of the numbers of cases of industrial accidents in the 1st three quarters of 2015 and 2016 in Hong Kong (*Summary of Occupational Safety and Health Statistics – 1st Three Quarters of 2016*, 2017)

Industrial accidents	1st three quarters of 2015 (No. of cases)	1st three quarters of 2016 (No. of cases)	Percentage change in figures
Construction	2755	2773	+0.7%
Food and beverage services	4045	3671	−9.2%
Manufacturing	1283	1111	−13.4%
Others	560	583	−3.9%
Total	8643	8093	−6.4%

2 Review of the Causes of Accidents in the Construction Industry

2.1 Causes of Accidents in the Construction Industry

There are many causes that lead to accidents in the construction industry. Hon, Chan, and Wong [5] believed that accidents are caused by the lack of working competence, poor behaviour, poor equipment or misuse of equipment, lack of training, etc. Misiurek and Misiurek [9] realized that human errors, instead of technical errors, are the major reasons leading to accidents. Li, Ji, Yuan, and Han [8] indicated that good climate or working environment is important for construction works' safety. Irumba [6] pointed out that in Kampala, Uganda, the congestion on the work site increases the accident rate.

2.2 Asymmetric Information Held by Different Stakeholders on Sites

Asymmetric information and project risk

Many experts believe that the problem of asymmetric information causes safety risks when conducting a project. Xiang, Zhou, Zhou, and Ye [12] indicated that the presence of transaction costs leads to the existence of symmetric and asymmetric information. Symmetric information may cause the risk of changes of interest rates, the fluctuation of exchange rates, and change politics. These risks can be predicted and are called objective risks. Regarding asymmetric information, different parties in a construction project can apply it to satisfy their interest. It leads to behaviour risk being of each party and this kind of project cannot be predicted. The objective risk and behaviour risk of the participants make up the project risk (Fig. 1).

According to the principle-agent theory, asymmetric information could cause problems of adverse selection and moral hazard [1]. Xiang, Huo, and Shen [12] believed that asymmetric information could lead to adverse selection and moral hazard that are harmful to a construction project. The problems will arise for different stakeholders on a construction site.

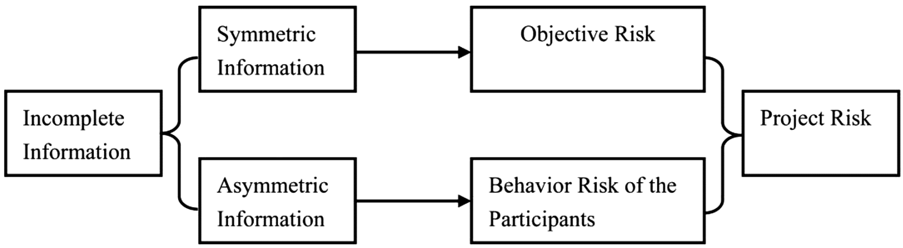

Fig. 1. Asymmetric information and project risk

Asymmetric information between different stakeholders

In a construction project, the project owner and contractor hire their own project managers. Thus, there are mainly four parties involved in a construction project. Asymmetric information will arise for these four parties and thus, there is a need to deal with the communication problems between them [2]. In detail, the project owner will hire a contractor at the beginning, and the contractor will perform for the project owner. As different parties have their own interests, the asymmetric information between the two parties will lead to conflict in a construction project (Fig. 2) [3].

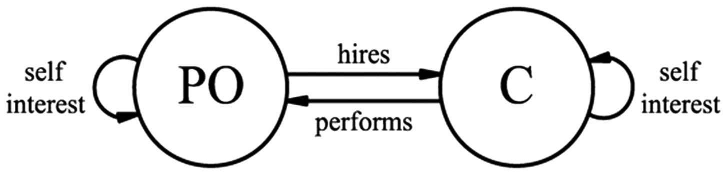

Fig. 2. Relationship between project owner (PO) and contractor (C) [3]

Furthermore, project owners and contractors hire their project managers to represent them at work. Figure 3 shows the relationship between these four parties. The project owner as well as contractor hire their own project managers who work for each of them. The project owner's project manager will supervise the project managers hired by the contractor. The contractor's project managers will communicate with the project

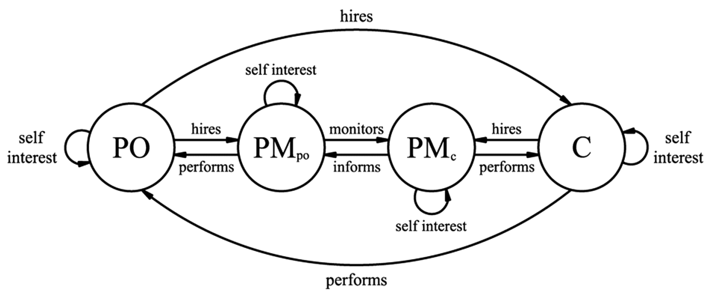

Fig. 3. Relationship between the project owner (PO), project owner's project managers (PMpo), contractor (C), and contractor's project managers (PMc) [3]

owner's project manager. Besides, these four parties also have their own interests and this will cause conflict in a construction project due to the asymmetric information held by each party [3].

3 Research Method

Questionnaires and interviews were applied in this research to collect data. In the process of interviewing, the author selected different kinds of workers (based on their age, sex, experience, etc.). The interview questions included the age of the interviewees, occupation of the interviewees, educational level, length of working, the size of working company, etc. The detailed content is shown in Table 2.

Table 2. Interview content

Interview content	Age of the interviewee
	Company size
	Education level
	If he/she is a smartphone user
	Length of service (year)
	Occupation
	Rank the five most important reasons for construction accidents for his/her type of construction
	Sex

4 Causes of Construction Accidents

This research approached different employees from the construction industry in different occupations. In the interviews or survey, all the respondents had to rank the five most important reasons that lead to construction accidents on building sites, bridges and tunnels.

4.1 Buildings

In the construction industry, accidents occur when workers do not possess sufficient knowledge about safety measures. Inadequate safety consciousness is one of the most important causes that lead to construction accidents on sites. A surveyor from Swire Properties Hong Kong contended that for the sake of convenience, many workers do not take enough safety precautions. Some workers do not wear safety helmets. Objects often fall on sites with high-rise buildings under construction. Without the helmets, workers can easily be injured or even die.

According to the interviewees, bamboo scaffolding safety is always considered as a major concern in the construction of buildings as the change of structure or shape raises the danger level for workers on a site. In the eyes of an engineering assistant working at SOCAM Development Limited, he ranked bamboo scaffolding as the second most important cause leading to accidents in high-rise buildings. In Hong Kong, in 2013, there were 1,751 registered bamboo scaffolders, according to the Construction Workers Registration Board, and roughly 200 scaffolding companies operate in the city (Ngo, 2013). The major problem of bamboo scaffolding is that it is not safe if the ties are not tied securely enough. Also, it is dangerous once there are falling objects onto the scaffolders because they can hardly avoid them.

Mr. Pang, a 23-year-old construction worker, ranked poor in-house keeping as the fourth reason leading to construction accidents in buildings. He saw a worker drop into a hole, which was supposed to be covered. After the investigation, the employer company discovered that it was because another construction worker had uncovered it. Another example provided by Mr. Pang was that the nails were put by a worker all around the construction site, which might cause many accidents.

Some of construction accidents happen in the process of building construction. Different people have different opinions towards the causes of construction accidents. The buildings can be separated into high-rise buildings (taller than 100 m) and low-rise buildings (equal to or less than 100 m).

4.2 Skyscrapers

Most interviewees thought that falling from a height (e.g. from scaffolding or a lifting frame) is the first most common high-risk building construction accident. The other factors suggested to contribute to the risk of accidents included the high working environment, improper handling and carelessness, lack of training and awareness, the falling of objects, and lack of experience.

The second most important cause of high-risk building construction accidents suggested was the lack of supportive equipment. The other answers to this question included bad working environment, improper handling and carelessness, falling from a height (from the scaffolding or lifting frame), falling of objects, and the high working environment.

Most interviewees believed that the third important reason was the improper use of equipment, which included not wearing safety belts and helmets. The other answers to this question included the bad working environment, machines, improper handling and carelessness, electric shock or accident, and the process of transportation.

Low-rise buildings

Most of the interviewees thought that falling from a height (from the building, the scaffolding or the lifting frame) was the first most common low-rise building construction accident. The other answers to this question included improper handling and carelessness, the improper use of equipment, not following safety rules, falling of objects, the lack of supportive equipment, and the process of transportation.

For the second most important reason of high-risk building construction accidents, most interviewees realized that the falling of objects from height is the most leading cause. The other answers to this question included falling from a height (from the building, the scaffolding or the lifting frame), improper use of equipment, lack of supportive equipment, high working environment, and bad working environment.

For the third question, the most common answer was also the falling of objects. The other answers to this question included the bad working environment, improper use of equipment, falling from a height (from the building, the scaffolding or the lifting frame), electric shock or accidents, the lack of supervision, as well as machine malfunction.

4.3 Bridges

Apart from the buildings, construction accidents on bridges are common. Among all causes of accidents on bridges, inadequate experience in the operation of the machines is one of the major culprits triggering accidents. The use of large machinery is needed in the building of bridges, according to a 26-year-old construction worker from Wing Fat Building Construction Ltd. For example, construction workers may not check the weight of the load to be lifted so it may exceed the safe working load. Besides, lifting gear such as hooks and shackles may not be checked as to whether there is any wear and tear.

One of the causes of bridge construction accidents is too long working hours. The labourers work for too many hours and it makes them tired. According to a Resident Survey Officer at Aecom, there is a report that a worker worked for 24 h continuously and died after falling into the sea. He held the belief that much engineering work is not allocated enough time to complete resulting in long working hours. As a result, accidents may happen easily if the workers are exhausted.

Adverse weather conditions can be another root sparking off construction accidents on bridges. If a construction project is carried out near coastal areas, humidity mists up the glass of transportation vehicles, like ferries and cars. With reference to a part-time engineer assistant at Prudence Construction Co. Ltd., some ferries or ships may crash into the bridges because they are not aware of their construction, especially when facing low visibility which might be due to adverse weather conditions like heavy rainfall, typhoons, tsunamis and so on.

The interviews show that most people believe that falling from a bridge is the first most common bridge construction accident. The other answers to this question included accidents related to machines, improper handling and carelessness, car accidents, falling of objects, and lack of experience.

Regarding the second most important reason for bridge construction accidents, most interviewees realized that a bad working environment would cause accidents. The other answers to this question included falling from a bridge, car accidents, the falling of objects, being distracted, and the lack of supportive equipment.

Most interviewees thought that the third important reason was falling from a bridge (despite we may argue that this not a reason; it is an accident. Many of the interviewees point out the same thing). The other answers to this question included electric shocks or accidents, a bad working environment, the process of transportation, unclear instructions, bad weather, as well as fire.

For the fourth question, the answer of falling from a bridge also became a major cause of accident. The other answers included electric shocks or accidents, a bad working environment, the lack of supportive equipment, the lack of training and awareness, and accidents related to machines.

Last but not least, for the fifth question, people thought that most accidents during the process of bridge construction are caused by a bad working environment. The other answers included the lack of supportive equipment, falling from the bridge, high working environment, improper use of equipment, and the process of transportation.

4.4 Tunnels

There are several causes of accidents in tunnel construction. Kikkawa, Itoh, Hori, Toyosawa, and Orense [7] found that in Japan, one of the major causes of tunnel construction accidents is rock falls. In addition to construction accidents on buildings and bridges, asymmetric information is one of the leading factors behind construction accidents in tunnels. Confined space could lead to accidents when it comes to the construction of tunnels. Confined space is unfavourable as a working environment as various kinds of injuries like loss of consciousness, asphyxiation or hyperthermia at work arise from gas, fumes, vapour or the lack of oxygen. On the other hand, according to a skilled labourer at Sun Wai Transportation Company, workers in a construction site for bridges might use some flammable gas to weld metal. If workers store flammable gases carelessly, it could lead to explosions and even contribute to the death of workers in the limited space.

The interview shows that most people think that inadequate ventilation is the first important reason behind tunnel construction accidents. The other answers to this question included the bad working environment (e.g. dark, narrow space, toxic gas), collapse, car accidents, lack of supportive equipment, and explosions. The second often answered important reason with regard to tunnel construction accidents was bad working environment. The other answers to this question included explosions, the lack of supportive equipment, accidents related to machines, car accidents, the falling of objects, and inadequate ventilation.

For the third most important reason, people also believed that the bad working environment (dark, narrow space, toxic gas) would be the most important. The other answers to this question included explosions, the improper use of equipment, lack of supportive equipment, car accidents, lift faults, and electric shocks or accidents. For the fourth question, the most common answer was also the bad working environment (dark, narrow space, toxic gas). The other answers included electric shocks or accidents, inadequate ventilation, the lack of training and awareness, falling from a height, and an untidy work site.

For the last question, poor working environment such as dark, narrow space, toxic gas were the reasons mainly pointed by the respondents. The other common answers included falling down stairwells, improper handling and carelessness, the process of transportation, inadequate ventilation, as well as accidents related to machines.

4.5 Summary

Different types of buildings have different causes of construction accidents. Table 3 summarizes the types of buildings with the three most important reasons for construction accidents in detail.

Table 3. Summary of the three most important reasons for construction accidents

Types of buildings	First most important reason for construction accidents	Second most important reason for construction accidents	Third most important reason for construction accidents
Skyscrapers	Falling from a height (from the scaffolding or the lifting frame)	Lack of supportive equipment	Improper use of equipment
Low-rise buildings	Falling from a height (from the building, the scaffolding or the lifting frame)	Falling of objects	Falling of objects
Bridges	Falling from a bridge	Bad working environment	Falling from a bridge
Tunnels	Inadequate ventilation	Bad working environment (dark, narrow space, toxic gas)	Bad working environment (dark, narrow space, toxic gas)

5 Suggestions for Improving Construction Safety

According to the research findings, the improvement can be separated according to the type of buildings.

For employees who work on skyscrapers, more supportive equipment (such as non-slip shoes, safety belts, etc.) should be provided. Some of the old equipment should be changed to new ones. Workers also need to learn the right way to use the equipment. More training programmes should be provided for employees, especially for those who work on high scaffolds; they need to be trained carefully to prevent them falling from a height.

For those who work on the construction sites of low-rise buildings, supportive equipment should be provided such as helmets, non-slip shoes, safety belts, etc. Before starting work, machines and the environment should be checked regularly in order to make sure the work site is in a safe condition.

For workers working on bridges, the equipment also should be well prepared such as safety belts, safety nets, etc. Workers who lack experience should be trained and learn more knowledge of operations in high working environments. In addition, there is a need for safety supervision to make sure that workers are safe.

For workers who work in tunnels, equipment such as goggles, oxygen masks, non-slip shoes, etc. should be well prepared. Before starting work, the machines and underground environment should be checked in order to make it safe.

6 Conclusion

This research tried to collect data from employees in the construction industry in Hong Kong to obtain some suggestions to improve construction safety. From the survey, the data show that the major accidents in skyscraper construction are falling from a height (from the scaffolding or lifting frame), lack of supportive equipment and the improper use of the equipment; for low-rise buildings, the major accidents include falling from a height and the falling of objects; the major bridge construction accidents include falling from the bridge and the bad working environment; for tunnel construction, the major causes are inadequate ventilation and the bad working environment (dark, narrow space, toxic gas). According to the causes collected from the survey, there are several suggestions including preparing supportive new equipment (safety belts, non-slip shoes, helmets, etc.) and replacing old ones, offering more training programmes for employees (especially those work on scaffolding), regularly checking the condition of the machines and the working environment before beginning work, providing safety supervision during the construction process, etc.

7 Limitation

Although the study has made a contribution, there are some limitations. As the questionnaire and interview could not cover everyone working in the construction industry, the study was based on the common situation and cannot include some extreme cases.

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Aviation Accident Analysis: A Case Study

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Abstract. This study is focused on an airplane crash case to analyze and identify the accident contributing factors. The accident occurred on 27th of December 1991 in a few minutes after a Scandinavian Airlines System plane departed from Stockholm on a route to Copenhagen, Denmark. It was found that the cause of this accident is a combination of several factors. Errors can result from ambiguously written procedures, inadequate training, unexpected operational situations or individual judgments. Situational awareness, environmental and crew coordination factors, as well as shortcomings in pilot technical knowledge, skills and experience, also can cause incidents. Other mistakes might be the result of improper airspace design or crew coordination.

Keywords: Airplane crash · Aviation safety · Accident cause analysis

1 Introduction

On 27th of December 1991, an aircraft of model MD-81 operated by Scandinavian Airlines System (SAS), flight SK 751 departed from Arlanda International Airport in Stockholm, Sweden, on a route to Copenhagen, Denmark. In a couple of minutes after the departure both engines failed and the emergency landing had to be made on a field. Unfortunately, it did not succeed and the aircraft was broken in three pieces on impact with the ground [1].

The aim of this study is to analyze the accident and identify the sequence of events and conditions that contributed or caused the crash. This paper is prepared on the basis of a study carried out at Chalmers University of Technology [2] and a literature survey as well.

2 Description of the Accident

The day before accident SAS MD-81 plane arrived to Stockholm from Zurich in late evening hours (around 22.00 h) and was parked at gate overnight with temperatures of around +1 °C [1]. There were left approximately 2550 kg of fuel in each wing tank. The next day aircraft was scheduled to leave Stockholm for Copenhagen at 08.30 h. In the following day, early morning, the temperature had dropped to −0 °C [3]. During the parking time clear ice had formed on the upper side of the wings.

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Checking routines by the ground crew member did not detect this phenomenon. The aircraft was fueled with 1400 kg of fuel and de-icing procedure started immediately before take-off. After de-icing the mechanic didn't check whether there was any clear ice on the upper side of the wings, since he had previously found none. The required preparation was completed and aircraft took-off at 08.47 h from Runway 08 [3].

Already after 5 s captain could hear a humming noise. After 25 s (at 1124 ft height) the right engine started to surge. Surging occurs when the compressor is no longer able to compress the incoming air to the pressure obtaining in the engine's combustion section and this result in violent air shots in the opposite flow direction [1].

The captain throttled back on the surging engine somewhat, but the surges continued until the engine stopped delivering thrust after 76 s of flight. When the flight had lasted 65 s the left engine also started to surge, which the pilots did not notice before this engine also lost thrust. This happened two seconds after the right engine had failed. When both engines had failed the crew prepared for an emergency landing. When the aircraft was entirely out of the cloud at a height of 300 to 250 m, a field in the direction of flight was chosen for an emergency landing. During the approach the aircraft collided with trees and a major part of the right wing was torn off. The tail of the aircraft struck the ground first and after the impact the aircraft slid along the ground for 110 m before stopping. The fuselage was broken into three pieces and no fire broke out. All 129 people on board survived and most without physical injury. One passenger suffered a disabling back injury [4]. Figure 1 shows the flight pass of SAS flight 751.

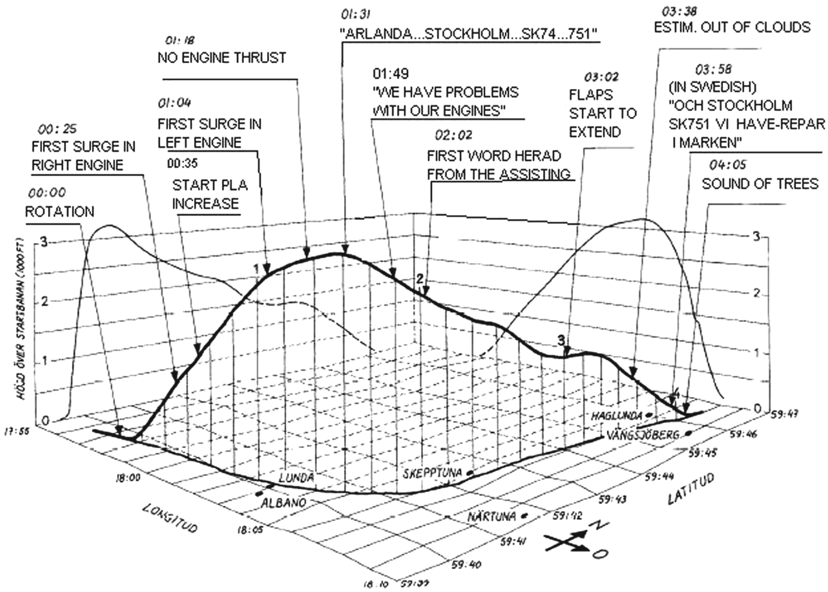

Fig. 1. Illustration of SAS flight 751 flight pass [1]

3 Identification of Root Causes

Modern business aircraft are technological marvels. Utilizing the big screen multifunction electronic displays that have replaced the dozens of traditional single purpose mechanical instruments in the cockpit, "smart" fuel control systems that protect the engines from exceeding specified temperature or power limits and advanced airfoil designs, that achieve both high-speed cruise and slow-speed stability, commercial jets and turboprops have attained an unprecedented level of efficiency and safety. Today, mechanical problems account for only a fraction of aircraft-related safety incidents.

These developments are welcome news to all which travel by air; but to focus solely on the machinery of flight is to overlook the most critical safety component. The fact is that even the most technologically sophisticated commercial jet is only as safe as the pilots flying it are. Analysts estimate that 70% to 90% of aviation accidents involve some degree of pilot error.

An airplane is now part of a complex modern technology system, and there are three aspects combined in safety matters within these systems as shown in Fig. 2. All combined, had an important influence in the occurrence of the accident.

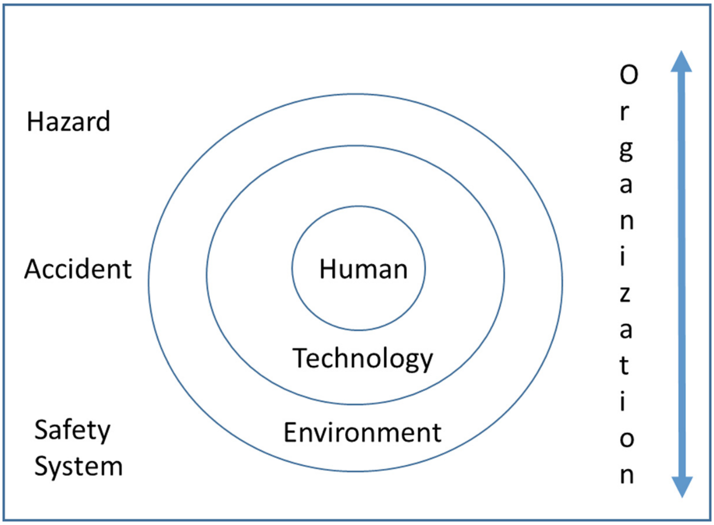

Fig. 2. Safety matter within complex technology system

The aircraft MD-81 crash can be called a system accident with a chain of different causes. Here we provide an identification of initiating events and states as causal factors.

3.1 Environment

Weather. The weather conditions on December 27,1991 at the time of departure in Arlanda airport was intermittent light snow, windy winter morning with the temperature approximately –0 °C.

During the rescue operation it was overcast but with no precipitation, with temperatures around 0 °C. The ground was frozen crust with a thin layer of snow.

Icy weather is a matter of life or death for the Federal Aviation Administration. Ten airline accidents during takeoffs between 1978 and 1997 are attributed to ice forming on jets. As a result, the FAA established tougher rules for aircraft de-icing on the ground.

Clear Ice. Clear ice that broke off from the wings and caused the damage to the engine fan stages. It led to engines surges and destruction the engines.

It is well known that clear ice can form on the upper surfaces of wings under conditions of high atmospheric humidity or rain in combination with greatly chilled wings. It is also well known that such ice is broken off through movements of the wings on liftoff.

During the flight from Zurich the fuel had become greatly chilled. On landing there were 2 550 kg of fuel in each wing tank, which represents approx. 60% of the tank volume. This volume of fuel was enough to chill the upper surfaces of the wings. The meteorological conditions for the formation of clear ice where almost optimal. The flight technician who inspected the plane during the night noted that clear ice had already formed on the wings. In addition, passengers saw during the de-icing that the indication tufts were not moving and on lift off that ice was coming off the wings. It is clear that "soft" objects being sucked into the engines initiated the engine damage.

3.2 People and Organization

(a) **Reported Incidents**

Several cases were reported related with the ice phenomenon on all DC-9 versions and these events were reported to the authorities, manufacturers and operators.

For instance, after a number of cases where clear ice has been found remaining on the wings following de-icing, Finnair summarized its experience in a report in 1985, in which the problem of undiscovered, unremoved clear ice was headlined as "The most difficult systematic threat to flight safety today".

For supervision, the Scandinavian countries have set up a special supervisory body, to exercise technical and operational flight supervision on its behalf.

In February 1990 it was noted that SAS had reported active work on "DC-9 Ice Ingestion" and also was participating in international cooperation in the area. As a result of this work SAS produced Swedish-language de-icing instructions for winter operations 1991/92. This was judged by STK to be good basic material for solving the clear ice problem. STK also made sure that the instructions were used in training.

Some recommendations were made before the accident concerning discovering clear ice. The manufacturer recommended the installation of warning triangles with indication tufts on critical wing areas.

(b) **Inspection procedures**

The problem of clear ice on this aircraft type had been known within SAS since 1985.

In various bulletins over the years the clear ice problem was described in detail and mentioned that the problem was considered the greatest current threat to flight safety. But the people responsible for the inspection of the aircraft did not follow these recommendations.

The people responsible should check the aircraft for any ice or snow that may affect performance. A visual checks from a ladder or when standing on the ground is not enough.

(c) **Lack of information in training**

In the MD-80 STUDY GUIDE that pilots use when training on the MD-80, clear ice was not mentioned. The computerized self-studies referred to current regulations in FOM and AOM. These contained no information on the clear ice problem. After the accident the first officer stated that he had never realized the extent of the clear ice problem during his training on the MD-80. In the AOM section that deals with what is termed walk-around inspection there was no special instruction regarding an ice check before flying. Also if clear ice is formed, the aircraft shall be inspected after de-icing to ensure that all-clear ice has been removed.

The normal checklist included no special item on ice and snow except for a point regarding de-icing with the engines running. In the associated expanded checklist it was stated for this control item only that the time required for the fluid to work should be verified against a table.

The technical division is responsible for de-icing being carried out correctly. In the division the clear ice problem was well known and had been dealt with in training, instructions and technical bulletins. Prior to the winter season, personnel affected at Arlanda were given training in de-icing.

Here, current instructions and general guidance concerning ice formation and de-icing had been compiled for personnel affected in Sweden. The de-icing instructions, which did not have the status of registered technical documentation, were used in training and were distributed to technicians and mechanics.

But even that the mechanic responsible for handing-over the aircraft was appointed by the company in June 1990 and trained in de-icing that autumn, was not able to report the clear ice formed at the accident.

(d) **De-icing procedure**

It is ultimately the captain's responsibility to ensure that de-icing is done with sufficient care. It is, however, the technical division that must answer for de-icing being performed and checked. Besides the bulletins issued within the technical division during the course of the year, training was organized before the start of the winter season for all personnel concerned. Each mechanic was provided with a checklist, which specified that he should check whether there was any clear ice by feeling the wing upper surfaces with his hand.

There were no detailed instructions in defined nomenclature that described how to check for the presence of clear ice, how the ice should be removed or how the follow-up check and the report to the captain should be effected. In the present case it should have been clear to the mechanic that he should check whether there was any clear ice, since rime had been noted on the underside of the wings in the tank area. He did perform this examination by climbing up on a ladder and, with one knee up on the leading edge of the left wing near the fuselage feel the upper side of the wing with one hand. He could not discover any clear ice there and concluded wrongly that there was no clear ice further. There was ice there, however, on an area which he, with this particular means of checking, could not reach. To be able to carry out an effective examination it would have been necessary for the mechanic to go out onto the wing, which was slippery because of the precipitation.

Since he could not find any clear ice before the de-icing, the mechanic had no reason, given the instructions in force, to check this again after de-icing had been carried out.

3.3 Technology

(a) **Knowledge of ATR within SAS**
At the time of the accident there was no knowledge of ATR (Automatic Thrust Restoration) within SAS. The pilots were therefore not trained on ATR and information about it was not included in their operational documentation. However, all the necessary information was given in the aircraft manufacturer's manuals available within the company. Hence ATR was described in manuals which every operator is obliged to know. Even though the system was originally developed for use in special procedures not applied by SAS, a sufficiently careful study of the manuals should have led to SAS noting the system and training its pilots in its function. If the pilots had been informed concerning ATR they would have had more chance of noticing the changeovers. They would then have been better prepared to take adequate action. It was a serious deficiency in flight safety that the pilots lacked knowledge of ATR and its function. It should be noted that in the event of loss of thrust from one engine during the takeoff phase, ATR must ensure that the ATS (Auto Throttle System) immediately regulates thrust in the functioning engine. The ATS always maneuvers the engine throttle levers simultaneously and equally. This means that ATR initiates increase of an engine thrust and affects the engine that caused the system to be activated. Therefore there is strong requirement for instructions on how pilots are to act in the event of engine surging during takeoff.

(b) **The combustion system failure**
Nothing has emerged to indicate that the aircraft's engines before the rotation had any technical fault that affected the development of engine surging. However, a manufacturing fault in a weld seam in the aircraft's main fuel duct to the left engine contributed to a fuel leak occurring in connection with the engine failure. The course of the failure was very similar in both engines. Mentioned before sequence of events will be now stated with more details:

Modern turbofan engines are sensitive to damage to fan blades and outer fan blade seals. Fan blade damage located on the blades outer tips is particularly critical. Such damage can at high engine power cause local fan tip stall. The fan tip stalls can increase and form "rotating cells" in the fan stage which called as continually rotating fan tip stalls.

The aerodynamic disturbances in the fan stage propagated themselves to the compressors and caused engine surging. As it was indicated before activated ATS through the effect of ATR caused an increase in throttle that contributed to the fact that the surging continued and intensified until the engine finally broke up. The risk of engine surging as a consequence of damage in the fan stages depends on the extent and character of the damage.

The surges subjected the engines to aerodynamic and mechanical stresses that became greater with the increasing engine power. The engine damage indicates that the stage 1 stators were finally broken up by these stresses and the engine failed. The increase in engine power also caused the left engine to surge and fail in the same manner. The impact damage found on the fan blade trailing edges was caused largely by broken-off stator pieces. The pieces then accompanied the airflow into the front compressors, causing extensive damage to their front stages. Blades and guide vanes in the rear parts of the compressors were damaged by pieces struck loose further forward in the engines.

When the engine compressors failed there was high air pressure and thereby a copious supply of oxygen. Local high temperatures were generated through friction between rotating, static and broken-off metal pieces. Titanium alloy pieces were thus ignited. Through a combination of high temperatures and mechanical load, holes were made in the engines' rear compressor cases, which serve, as pressure vessels for the rear compressors. The pressure and temperature thereby decreased rapidly, causing the titanium fire to stop spontaneously after the brief break-up phase.

Thanks to the fire alarm system the first officer has recognized the risk and initiated the engine fire extinguishing system.

As the further consequence of the engine failure was electrical power failure that inactivated captain's Electronic Flight Instrument System presentation that caused more difficult to steer the aircraft in emergency landing.

3.4 Organizational

Negligent Attitude by SAS. The risk of ingestion of clear ice by the engines of the aircraft type has been known for many years. As early as 1985 a DC-9-51 suffered serious engine damage for this reason. On the MD-80 series, the risk is greater due to the configuration of the wing tanks and the larger engine air intake area. The manufacturer has therefore over the years taken a number of steps to inform operators of the problem and has distributed numerous service bulletins intended to reduce the risks.

The problem has thus long been known within SAS. In 1987 the aircraft were equipped with warning triangles with indication tufts to facilitate the discovery of clear ice. It was stated that it is the captain's responsibility to check the presence of snow and ice which might affect the aircraft's performance.

In the training of MD-80 pilots the clear ice problem has not been specially dealt with; nor were there any special written instructions for the pilots' action if there was a risk of clear ice. If the pilots had more knowledge and unambiguous instructions, they would probably have been more alert to the risk of clear ice formation.

Technical personnel were thus familiar with the clear-ice problem through training and information. In the Board's view, however, the clear-ice problem as dealt with in LMH, which is the formal governing document for direct work, had an obscure position and lacked detailed instructions on how the check for clear ice should be carried out; nor was there any follow-up on how the check should be performed in daily practice. There was no routine for reporting on observations regarding clear ice. Though, the technician who inspected the aircraft during the night noted the presence of clear ice, but there was no instructions obliging him to report this to the mechanic who was to carry out the departure check next morning.

Furthermore, the technical personnel had no access to suitable aids for checking effectively. To reach the critical area on the upper side of the wing without risking an accident, either special tools or specially built ladders would have been required. It must be considered remarkable that the numerous different warning signals on the risks associated with clear ice that have reached SAS over the years have not led to effective action being taken to ensure that aircraft did not take off with clear ice on their wings.

It is obvious that SAS self-monitoring has been deficient regarding the handling of the clear-ice problem. It also emerges that the Scandinavian Civil Aviation Supervisory Agency was not aware of the deficient quality assurance. The Board points out that the idea of self-monitoring presupposes that the supervisory authority ensures that the company possesses a well functioning system of quality assurance.

4 Conclusion

The cause of this accident is the combination of several factors, ambiguously written procedures, inadequate training, unexpected operational situations or individual judgments. Situational awareness, environmental and crew coordination factors, as well as shortcomings in pilot technical knowledge, skills and experience, also can cause accidents. Other mistakes might be the result of improper airspace design or crew coordination.

As an initial event, the clear ice formed on the upper surface of the wings was not detected and de-iced well. The company instruction, procedures and even the equipment were not sufficient to remove the clear ice from the wing surface. Hence during the take-off the clear ice was broken off the wings and ingested by the engines and caused damage the engine fan stages, which led to engine surges and failure. The pilot had no sufficient knowledge and training to identify the problem and taking the necessary action. Furthermore, there was no knowledge for applying Automatic Thrust Restoration system (ATR) within the company (SAS). Therefore it was activated and increased the engine power without the pilot knowledge. Another contributing cause was poor emergency landing responses in terms of speed and flap position for approach and landing.

Finally, it may be concluded that unsafe pre-conditions which had been created by SAS organization in terms of training, instruction, operational procedures etc. were blamed for pilot and technicians errors and mistakes which led to the crash.

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European Countries Social and Working Conditions Association with Fatal and Non-fatal Occupational Accidents

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Abstract. The study reported in this paper analyzed the determinants of occupational accidents from a social and a working conditions combined perspective, considering the level of analysis of the European nation. Fatal and non-fatal work accidents in 2014, collected and provided by Eurostat, are correlated with country by country results of the 7th European Social Survey (ESS) (2014 data). This informs on work accident determinants of the European Social Dimensions reported on the ESS. Moreover, considering data from the 6th European Working Conditions Survey (2015 data), working conditions, on a country by country basis as well, are further considered and analyzed from the perspective of fatal and non-fatal accidents and from the perspective of social dimensions. This multiple pronged study of association unveils interesting associations between fatal and non-fatal work accidents and working conditions, as well as between fatal and non-fatal work accidents and social dimensions, and also, between social dimensions and working conditions, taking the European country as a unit of analysis. The findings shed light on the interconnectedness of the distinct domains under study, as well as informing policy development towards creating tailor made approaches suiting each particular country reality within the countries encompassed in the analysis.

Keywords: Social dimensions · Occupational health and safety · International analysis

1 Introduction

Humanitarian and economic considerations alike prompt the need to improve working conditions, which is a collective concern. A safe and healthy working environment is an essential element of the quality of work. A territory populated by more than five hundred million people, the European continent boasts high levels of diversity, which has been studied and analyzed in several dimensions, cross-sectionally and longitudinally. European Union institutions have been carrying out themselves, and, or, sponsoring academic institutions to do the analysis and monitoring of a great set of indicators across the continent, including social dimensions, working conditions and fatal and non-fatal work injuries.

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In an effort to continuously reduce work accidents, understanding their social and working conditions determinants may shed light on the need for particular policy measures aiming at improving social dimensions and working conditions across the continent. The study reported in this paper aims providing a contribution to the understanding of the association of social factors and working conditions with fatal and non-fatal accidents across Europe. In particular, the study's objective is to analyze the determinants of fatal and non-fatal accidents at work from a social and working conditions combined perspective, considering the level of analysis of the nation. In this paper, the most recent EUROSTAT statistics of EU fatal and non-fatal accidents at work are first presented and then correlated (with the assistance of IBM SPSSS v.23) with selected country by country results of the 7th European Social Survey (2014 data) [1]. This informs on social determinants (selected European Social Dimensions reported on the 2014 ESS - Round 7) of fatal and non-fatal accidents at work. Additionally, considering data from the 6th European Working Conditions Survey (2015 data) [2], selected aspects of working conditions, on a country by country basis as well, are further considered and analyzed from the perspective of social dimensions and from the perspective of accidents at work, taking the European country as a unit of analysis. The findings shed light on the interconnectedness of the distinct domains under study, as well as informing policy development towards creating tailor made approaches suiting each particular country reality within the sample of countries encompassed in the analysis.

2 Fatal and Non-fatal Accidents at Work (2014 Data)

Non-fatal and fatal accidents at work in the European Union (EU) are collected within the framework of the European statistics on accidents at work (ESAW) administrative data collection. In ESAW methodology an accident at work is defined as a discrete occurrence during the course of work which leads to physical or mental harm. Fatal accidents at work are those that lead to the death of the victim within one year. Non-fatal accidents at work collected within ESAW are those that imply at least four full calendar days of absence from work (they are sometimes also called 'serious accidents at work'). Non-fatal accidents at work often involve considerable harm for the workers concerned and their families and they have the potential to force people, for example, to live with a permanent disability, to leave the labor market, or to change job; indeed, they result in a considerable number of days of work being lost [3].

The most recent statistics of EU fatal and non-fatal accidents at work available from EUROSTAT are shown on Table 1. They are depicted both in absolute terms and as per capita values, considering the total population of the country (as of January 1st 2015, according to EUROSTAT [4]).

Table 1. Fatal and Non-fatal accidents at work data from 2014 (EUROSTAT) for 29 European countries [5] (per capita values obtained by combining data [4, 5]).

Country	Fatal accidents at work	Fatal acc. at work per capita [/million]	Non-fatal accidents at work	Non-fatal work acc. per capita [/thousand]
Austria	126	14.7	65,418	7.6
Belgium	52	4.6	65,587	5.9
Czech Republic	118	11.2	42,306	4.0
Denmark	38	6.7	54,157	9.6
Estonia	16	12.2	6,288	4.8
Finland	22	4.0	47,432	8.7
France	589	8.9	724,662	10.9
Germany	500	6.2	847,370	10.4
Hungary	81	8.2	19,491	2.0
Ireland	47	10.2	18,115	3.9
Lithuania	55	18.8	3,120	1.1
Netherlands	45	2.7	87,964	5.2
Norway	61	11.8	10,108	2.0
Poland	263	6.9	76,274	2.0
Portugal	160	15.4	130,153	12.5
Slovenia	25	12.1	12,314	6.0
Spain	280	6.0	387,439	8.3
Sweden	40	4.1	35,296	3.6
Switzerland	74	9.0	86,346	10.5
United Kingdom	111	1.7	244,948	3.8
Bulgaria	117	16.2	2,246	0.3
Croatia	26	6.2	11,669	2.8
Greece	28	2.6	3,410	0.3
Italy	522	8.6	313,312	5.2
Latvia	41	20.6	1,725	0.9
Luxembourg	10	17.8	7,183	12.8
Malta	4	9.3	2,632	6.1
Romania	272	13.7	3,396	0.2
Slovakia	40	7.4	8,552	1.6

3 Selected Dimensions of the European Social Survey (2014 Data)

The European Social Survey (ESS) [1] is an academically driven cross-national survey that has been conducted across Europe since its establishment in 2001. Every two years, face-to-face interviews are conducted with newly selected, cross-sectional samples. The survey measures the attitudes, beliefs and behavior patterns of diverse populations in more than thirty nations.

For the purpose of the analysis reported on this paper, a selection was made of 16 indicators extracted from the ESS round 7 2014 data, using as criteria to extract no more than two questions from each of the core section themes (media and social trust, politics, subjective well-being, gender and household, socio demographics and human values), with the exception of human values, where more variables were extracted, in order to match them with the cultural dimensions presented in Sect. 2. Table 2 depicts the result of the selection. The selection was subjectively carried out by the researcher, based on the perception of the most impactful themes covered in the ESS7 regarding working conditions.

Table 2. Variables of the ESS round 7 (2014) [1] core questionnaire selected for analysis.

Core section theme	Data/Variables selected
Media and Social Trust	ppltrst: Most people can be trusted or you can't be too careful pplhlp: Most of the time people helpful or mostly looking out for themselves
Politics	trstlgl: Trust in the legal system stflife: How satisfied with life as a whole
Subjective Well-Being	sclmeet: How often socially meet with friends, relatives or colleagues health: Subjective general health
Gender and Household	gndr: Gender agea: Age of respondent, calculated
Socio demographics	edulvlb: Highest level of education wrkctra: Employment contract unlimited or limited duration
Human values	ipeqopt: Important that people are treated equally and have equal opportunities ipshabt: Important to show abilities and be admired ipfrule: Important to do what is told and follow rules impfree: Important to make own decisions and be free ipadvnt: Important to seek adventures and have an exciting life imptrad: Important to follow traditions and customs

Selected average scores per country were obtained from the dataset (ESS round 7) and are shown in Tables 3 and 4. In this process, the response scale items were considered in a question by question approach (answer ranges shown to survey respondents are given in the Tables captions).

Table 3. Part 1 of 2 of selected average scores per country obtained from the dataset (ESS round 7) (legend of headings given in Table 2) (ppltrst scale: 0-You can't be too careful—10-Most People can be trusted; pplhlp scale: 0-People mostly look out for themselves – 10-People mostly try to be helpful; trstlgl scale: 0-no trust at all – 10-complete trust; stflife scale: 0-extremely dissatisfied – 10-extremely satisfied; sclmeet scale: 1-never – 7-every day; health scale: 1-very good – 5-very bad) [1].

Country	ppltrst	pplhlp	trstlgl	stflife	sclmeet	Health
Austria	4.968	5.081	5.638	7.380	4.867	1.979
Belgium	5.016	4.632	5.020	7.452	5.131	2.053
Czech Republic	4.479	4.548	4.659	6.641	4.485	2.086
Denmark	6.903	6.070	7.404	8.356	5.320	1.928
Estonia	5.574	5.015	5.215	6.401	4.180	2.563
Finland	6.739	5.971	6.758	7.922	5.014	2.187
France	4.666	4.704	5.131	6.395	5.185	2.294
Germany	5.092	5.263	5.739	7.422	4.727	2.339
Hungary	4.175	4.359	4.623	5.834	3.476	2.464
Ireland	5.128	5.847	5.291	6.943	4.526	1.859
Israel	5.153	5.032	5.554	7.376	4.626	1.925
Lithuania	4.770	4.454	4.335	5.812	4.006	2.483
Netherlands	5.975	5.629	5.909	7.602	5.414	2.181
Norway	6.617	6.062	7.188	7.942	5.353	1.942
Poland	3.948	3.662	3.545	6.932	4.148	2.327
Portugal	3.667	3.991	3.708	5.800	5.691	2.587
Slovenia	4.069	4.933	3.131	6.573	4.564	2.386
Spain	4.828	4.351	4.018	6.965	5.222	2.314
Sweden	6.245	6.110	6.385	7.903	5.450	1.966
Switzerland	5.719	5.690	6.583	8.077	5.136	1.876
United Kingdom	5.376	5.920	5.548	7.163	4.808	2.140

Table 4. Part 2 of selected average scores per country obtained from the dataset (ESS round 7) (legend of headings given in Table 2) (scale: 1-Very much like me – 6-Not like me at all) [1].

Country	ipeqopt	ipshabt	ipfrule	impfree	ipadvnt	imptrad
Austria	1.952	2.967	3.141	1.933	3.903	2.565
Belgium	2.039	3.105	3.158	2.126	3.857	2.711
Czech Republic	2.497	3.301	2.695	2.354	3.740	2.621
Denmark	2.113	3.514	2.810	2.163	3.449	2.758
Estonia	2.364	3.573	3.328	2.266	4.106	2.926
Finland	1.947	3.836	3.018	2.142	3.890	3.031
France	1.851	3.503	3.845	2.581	4.215	3.349
Germany	1.887	3.590	3.563	1.921	4.288	2.973
Hungary	2.022	2.615	3.295	2.062	3.792	2.445

(*continued*)

Table 4. (*continued*)

Country	ipeqopt	ipshabt	ipfrule	impfree	ipadvnt	imptrad
Ireland	2.075	2.884	3.122	2.212	3.666	2.581
Israel	1.974	2.374	2.724	1.953	3.565	2.453
Lithuania	2.461	3.278	3.353	2.606	3.951	2.547
Netherlands	2.094	3.287	3.013	2.039	3.727	2.888
Norway	2.123	3.714	2.736	2.389	3.720	3.016
Poland	1.912	3.100	2.429	2.070	4.031	2.129
Portugal	2.140	3.213	3.451	2.314	4.350	2.884
Slovenia	1.715	2.447	3.031	1.813	3.708	2.392
Spain	1.622	3.451	3.264	2.104	4.026	2.703
Sweden	1.765	3.545	3.337	2.247	3.810	3.170
Switzerland	1.918	2.962	3.353	1.741	3.750	2.800
United Kingdom	2.022	3.228	3.350	2.136	3.837	2.874

4 Selection of Dimensions from the European Working Conditions Survey (2015 Data)

Since its launch in 1990, the European Working Conditions Survey (EWCS) has provided an overview of working conditions in Europe [6]. Themes covered today include employment status, working time duration and organization, work organization, learning and training, physical and psychosocial risk factors, health and safety, work-life balance, worker participation, earnings and financial security, as well as work and health. For the purpose of the analysis reported on this paper, a selection was made of indicators extracted from the 6th EWCS 2015 data [2]. Tables 5 and 6 depict the

Table 5. Physical variables of the EWCS 2015 [6] selected for analysis.

Variable	[are you exposed at work to…? does your main job involve…?]
Q29a	Vibrations from hand tools, machinery etc.
Q29b	Noise so loud that you would have to raise your voice to talk to people
Q29c	High temperatures which make you perspire even when not working
Q29d	Low temperatures whether indoors or outdoors
Q29e	Breathing in smoke, fumes (such as welding or exhaust fumes), powder or dust (such as wood dust or mineral dust) etc.
Q29g	Handling or being in skin contact with chemical products or substances
Q29i	Handling or being in direct contact with materials which can be infectious, such as waste, bodily fluids, laboratory materials, etc.
Q30a	Tiring or painful positions
Q30b	Lifting or moving people
Q30c	Carrying or moving heavy loads
Q30e	Repetitive hand or arm movements
Q30g	Handling angry clients, customers, patients, pupils etc.
Q30h	Being in situations that are emotionally disturbing for you
Q30i	Working with computers, laptops, smartphones etc.

Table 6. Psychosocial variables of the EWCS 2015 [6] selected for analysis.

Variable	[to what extent do you agree with the following statements about your job…?]
Q89c	I receive the recognition I deserve for my work
Q89d	I generally get on well with my work colleagues
Q89e	The organization I work for motivates me to give my best job performance
Q89f	I get on better with my children because I have a job
Q89g	I might lose my job in the next 6 months
Q89h	If I were to lose or quit my current job, it would be easy for me to find a job of similar salary

Table 7. Part 1 of 2 of selected average scores per country obtained from the dataset (EWCS 2015 [6]) (legend of headings given in Table 5) (scale: 1 - All of the time—7 - Never).

Country	Q29a	Q29b	Q29c	Q29d	Q29e	Q29g	Q29i	Q30a	Q30b	Q30c
Austria	6.17	5.92	6.01	6.40	6.42	6.34	6.45	5.24	6.61	5.75
Belgium	6.43	6.07	6.31	6.38	6.46	6.43	6.43	5.37	6.51	5.85
Czech Republic	6.27	5.96	6.23	6.35	6.40	6.45	6.61	5.86	6.69	5.84
Denmark	6.35	5.80	5.99	6.12	6.59	6.50	6.29	5.85	6.60	5.96
Estonia	5.96	5.80	6.37	6.14	6.31	6.30	6.58	5.32	6.67	5.71
Finland	6.05	5.62	6.10	6.08	6.13	6.18	6.33	5.53	6.57	5.61
France	6.11	5.76	6.15	6.23	6.29	6.24	6.41	5.16	6.54	5.68
Germany	6.07	5.92	6.18	6.40	6.45	6.31	6.53	5.42	6.67	5.88
Hungary	5.95	6.00	6.14	6.12	6.23	6.14	6.40	5.27	6.51	5.85
Ireland	6.36	6.05	6.30	6.18	6.59	6.27	6.28	5.78	6.44	5.76
Lithuania	5.98	5.81	6.18	6.13	6.24	6.28	6.31	5.06	6.69	5.63
Netherlands	6.42	6.15	6.08	6.30	6.50	6.58	6.45	5.74	6.57	5.97
Norway	6.14	5.88	6.25	5.99	6.54	6.40	6.25	5.97	6.35	5.67
Poland	5.93	5.69	5.94	6.12	6.22	6.14	6.49	5.17	6.64	5.72
Portugal	6.08	6.26	6.35	6.47	6.55	6.57	6.68	5.01	6.56	6.03
Slovenia	6.10	5.63	5.91	6.22	6.33	6.38	6.53	4.96	6.67	5.88
Spain	6.06	5.84	5.42	5.92	6.37	6.07	6.36	4.66	6.52	5.37
Sweden	6.32	5.73	6.11	6.20	6.44	6.36	6.33	5.34	6.38	5.60
Switzerland	6.18	6.06	6.10	6.30	6.43	6.37	6.48	5.24	6.68	5.91
United Kingdom	6.47	6.01	6.16	6.11	6.45	6.16	6.24	5.74	6.49	5.68

result of the selection regarding physical and psychosocial exposures. The selection was subjectively carried out by the researcher, based on the perception of the most impactful themes covered in the 6th EWCS 2015 data. Selected average scores per country were obtained from the dataset (Tables 7 and 8). In this process, the response scale items were considered in a question by question approach (answer ranges shown to survey respondents are given in the Tables captions).

Table 8. Part 2 of 2 of selected average scores per country obtained from the dataset (EWCS 2015 [6]) (legend of headings given in Table 5) (scale for Q30: 1 - All of the time – 7 – Never; scale for Q89: 1-Strongly Agree – 5-Strongly disagree).

Country	Q30e	Q30g	Q30h	Q30i	Q89c	Q89d	Q89e	Q89f	Q89g	Q89h
Austria	4.68	5.69	5.54	4.29	2.13	1.57	2.24	2.72	4.13	3.24
Belgium	4.53	5.56	5.88	4.04	2.23	1.54	2.22	2.68	4.09	3.18
Czech Republic	4.48	5.89	5.83	4.98	2.30	1.74	2.39	2.56	3.62	3.37
Denmark	4.52	5.86	5.85	3.22	1.99	1.21	2.07	2.27	4.44	2.75
Estonia	3.94	5.87	5.78	4.27	2.31	1.53	2.32	2.47	3.67	3.09
Finland	3.86	6.02	5.62	4.36	2.04	1.29	2.01	2.12	4.15	3.15
France	4.34	5.44	5.72	4.51	2.33	1.60	2.44	2.84	4.18	3.20
Germany	4.91	5.74	5.83	4.93	2.35	1.58	2.40	2.90	4.19	3.17
Hungary	4.68	5.87	5.92	5.06	2.42	1.82	2.36	2.30	3.79	3.37
Ireland	4.74	5.50	6.17	4.20	2.20	1.39	2.19	2.11	4.07	3.23
Lithuania	4.21	5.66	5.21	5.14	2.50	1.71	2.75	2.38	3.68	3.11
Netherlands	4.33	5.85	6.06	3.74	2.02	1.26	2.12	2.52	3.89	3.35
Norway	4.73	5.86	5.93	3.54	1.88	1.20	1.92	2.16	4.44	2.72
Poland	4.42	5.47	5.51	5.11	2.54	1.88	2.52	2.48	3.46	3.11
Portugal	3.86	5.20	6.18	5.24	2.27	1.49	2.24	2.73	3.57	3.88
Slovenia	3.84	5.51	5.44	4.26	2.78	1.42	2.37	2.11	3.65	3.52
Spain	3.64	4.81	5.49	4.68	2.30	1.49	2.31	3.05	3.60	3.47
Sweden	4.19	5.56	5.78	3.59	2.27	1.46	2.34	2.45	4.21	2.69
Switzerland	4.58	5.37	5.66	4.52	2.08	1.61	1.99	2.71	4.14	3.01
United Kingdom	4.31	5.50	5.99	3.79	2.29	1.48	2.28	2.34	4.04	2.86

5 Results of Analysis of Association

Association between the fatal and non-fatal accidents at work statistics (in per capita formulation) presented in Sect. 2, and the selected social dimensions presented in Sect. 3 was made based on data from 20 countries that were matched across the two datasets. Table 9 depicts the pairs of variables where Pearson correlation factors above 0.45 were found. Both dimensions of accidents at work statistics are equally salient in this analysis. The social dimensions that are more salient in this analysis are those of satisfaction with life as a whole, frequency of social meetings and importance given to equally of treatment and opportunities as well as of following rules.

Table 9. Strong Pearson correlations (above 0.45 in absolute value) resulting from associating the fatal and non-fatal accidents at work statistics (in per capita formulation) with selected dimensions of the ESS7 [1]; variable names explained in Sect. 2 and Table 2; p-values shown in parentheses; n = 20.

Accidents at work/ESS7	stflife	sclmeet	ipeqopt	ipfrule
Fatal accidents at work	−0.555 (0.011)	–	0.457 (0.043)	–
Non-fatal accidents at work	–	0.581 (0.007)	–	0.451 (0.046)

Association between the fatal and non-fatal accidents at work statistics (in per capita formulation) presented in Sect. 2, and the selected working conditions dimensions presented in Sect. 4 was made based on data from 20 countries that were matched across the two datasets. Table 10 depicts the pairs of variables where Pearson correlation factors above 0.45 were found. Both per capita dimensions of accidents at work statistics are equally salient in this analysis. The physical working dimensions that is most salient in this analysis of association concerns vibrations from hand tools and machinery. The psychosocial working dimensions that display a great number of associations with the accidents at work statistics are those concerned with the average per country score of responses given to 'getting on better with own children because of having a job'. A third set of associations concerns the correlation between selected social and working conditions dimensions (Table 11). Most salient social dimensions in the analysis are peoples' perceived helpfulness, subjective general health, peoples' perceived trustworthiness, the trustworthiness of the legal system and the level of satisfaction with life as a whole. In what concerns physical working conditions, the variables most involved in the strong correlations are experiencing tiring or painful positions and working with electronic devices. Salient psychosocial factors are recognition for work, organization motivated performance, job insecurity and prospects of finding a new job if needed.

Table 10. Strong Pearson correlations (above 0.5 in absolute value) resulting from associating the fatal and non-fatal accidents at work statistics (in per capita formulation) with selected dimensions of the 6th EWCS [2] (inverted answer coding); variable names explained in Sect. 2 and Tables 5 and 6; p-values shown in parentheses; n = 20.

Accidents at work/6th EWCS	Q29a	Q89f
Fatal accidents at work	−0.482 (0.031)	–
Non-fatal accidents at work	–	0.534 (0.015)

Table 11. Strong Pearson correlations (above 0.5 in absolute value) resulting from associating the selected the ESS7 [1] with selected dimensions of the 6th EWCS [2] (inverted answer coding); variable names explained in Tables 2, 5 and 6; ** correlation is significant at the 0.01 level (2-tailed); * correlation is significant at the 0.05 level (2-tailed); n = 20.

ESS7/6EWCS	ppltrst	pplhlp	trstlgl	stflife	sclmeet	health	gndr	edu-lvlb	ip-eqopt	ipshabt	ip-advnt	imptrad
Q29a	–	.561*	–	.504*	–	−.676**	–	–	–	–	−.527*	–
Q29c	–	–	–	–	–	–	–	–	.638**	–	–	–
Q29e	–	–	–	–	.572**	−.512*	–	–	–	–	–	–
Q29g	–	–	–	–	.505*	–	–	–	–	–	–	–
Q29i	−.567**	−.573**	–	–	–	–	–	–	–	–	–	–
Q30a	.586**	.643**	.661**	–	–	−.583**	–	.546*	–	–	−.551*	–
Q30e	–	–	–	–	–	−.506*	–	–	–	–	–	–
Q30g	–	–	–	–	–	–	–	.670**	.520*	–	–	–
Q30i	−.779**	−.806**	−.686**	−.717**	–	.633**	–	−.522*	–	–	.618**	–
Q89c	−.761**	−.623**	−.841**	−.672**	−.579**	.619**	.509*	–	–	−.525*	–	–
Q89d	−.716**	−.737**	−.583**	−.580**	−.664**	–	–	–	–	–	–	–
Q89e	−.645**	−.646**	−.683**	−.694**	−.568**	.589**	.598**	–	–	–	–	–
Q89f	–	–	–	–	–	–	–	–	–	–	.626**	–
Q89g	.753**	.796**	.879**	.731**	–	−.701**	−.627**	.605**	–	–	–	.564**
Q89h	−.735**	−.663**	−.729**	−.642**	–	.571**	–	−.785**	–	–	–	–

Linear regression modelling (forward method) of fatal work accidents per capita was pursued, taking as independent variables all other variables present in this study. This modelling effort resulted in a determination coefficient of 0.308, with a single standardized coefficient of satisfaction with life as a whole at −0.555, with a significance level of 0.011. Adding the national dimensions of culture [7–14] to the independent variable pool in the regression of fatal accidents at work, yields a determination coefficient of 0.631, for the cultural dimension of individuality at −0.653 standardized coefficient ($p < 0.001$) and the importance of equal treatment and opportunities at 0.521 standardized coefficient ($p = 0.003$). Linear regression modelling (forward method) of non-fatal work accidents per capita ensued, taking as independent variables all remaining variables included in the study, except for fatal accidents at work. This modelling effort led to a very high determination coefficient of 0.901, based on a six independent variables model (Table 12). The regression model includes four social variables (education level, gender imbalance, importance given to rules and frequency of socializing) and two occupational exposures (lifting or moving people and handling angry clients). When national dimensions of culture [7–14] are added to the pool of independent variables for linear regression, the determination coefficient increases slightly to 0.937 with four social variables (gender imbalance, importance given to rules and frequency of socializing), tow occupational exposures (lifting or moving people and being in emotionally disturbing situations) and one cultural dimension (long term orientation versus short term orientation). The standardized coefficients for these variables and the significance levels are shown in Table 13.

Table 12. Standardized coefficients for the linear regression of the dependent variable 'non-fatal accidents per capita' on social and occupational exposure independent variables (coding of variables presented in Tables 2 and 5); n = 20.

Independent variable	Standardized coefficient	Significance
sclmeet	0.402	0.007
Q30b	0.584	<0.001
Ipfrule	0.609	<0.001
Gndr	−0.605	0.001
Edulvlb	−0.522	0.002
Q30g	0.359	0.026

Table 13. Standardized coefficients for the linear regression of the dependent variable 'non-fatal accidents per capita' on national dimensions of culture and social and occupational exposure independent variables (coding of variables presented in Tables 2 and 5); n = 20.

Independent variable	Standardized coefficient	Significance
sclmeet	0.331	0.007
Q30b	0.867	<0.001
Ipfrule	0.675	<0.001
Long term versus short term orientation	−0.447	<0.001
gndr	−0.483	<0.001
Q30h	0.187	0.042

6 Discussion

The results of association suggest that countries where people report a lower average degree of satisfaction with life as a whole (e.g. Portugal, Lithuania, Hungary) are bound to incur higher number of per capita fatal accidents at work. The moderate correlation found between the latter and the average score given by people to the importance of equal treatment and equal opportunities, suggests that countries where people on average give more relative importance to this issue (e.g. Spain, Slovenia) show a moderate tendency to display higher numbers of per capita fatal accidents at work than countries where this issue is given lower importance (e.g. Czech Republic, Lithuania). However, other factors seem to be at play, including the aforementioned degree of satisfaction with life as a whole and the working conditions dimensions discussed in the following paragraph.

Analysis of correlation between fatal accidents at work and physical job exposures yielded a moderate correlation for vibrations from hand tools and machinery, indicating that countries where on average more people are subjected to this physical exposure at work (e.g. Poland, Hungary, Estonia) show a moderate tendency to suffer a relatively higher rate of fatal accidents per capita. The single psychosocial factor that correlated with accidents at work was 'getting on better with own children because of having a job' which associated strongly with non-fatal work accidents. Countries where people on average show higher levels of agreement with the aforementioned EWCS survey item (e.g. Slovenia, Ireland, Finland, Norway) tend to have relatively lower per capita rates of non-fatal accidents at work. Associations of physical exposures with self-perceived health were negative for vibrations, breathing in some and fumes, experiencing tiring or painful positions and performing repetitive hand or arm movements. Job security correlated very notably with trust in the legal system and recognition for work. The greatest absolute value of correlation found in the study was 0.879 between job insecurity and trust in the legal system.

Regression results for fatal accidents at work point to satisfaction with life as a whole as the single predictor, when encompassing in the model the social and working conditions variables selected for this study. However, when adding cultural factors to the two aforementioned domains, the results suggest that countries with lower individuality and higher collective national culture (e.g. Slovenia, Portugal) and where at the same time, on average, citizens place relatively higher important on equal treatment and opportunities (e.g. Slovenia) are bound to incur in relatively higher fatal work accident rates per capita. Linear regression of non-fatal work accidents shows a very high determination coefficient on two six variable models. There are four variables common to both models, which are gender imbalance (the more females the less accidents), lifting or moving people (more lifting yields more accidents), importance given to rules (the more disregard for rules the more accidents) and meeting for socializing (the more frequent social gatherings the more accidents at work).

There are limitations in this study. First and foremost, given the breadth of the ESS and ECWS surveys, a selection of variables was made, which carries a level of subjectivity. Moreover, the size of the level of analysis in this study (country level) precludes fine grained differences which are inherently present in any big population group, such as a nation. This notwithstanding strong correlations were found between all the three datasets associated in this study. Moreover, the European countries included in each of the three datasets considered was not the same; the intersection of the three datasets yielded a sample of twenty European countries. Hence, the scope of analysis while continent wide is not completely encompassing.

7 Conclusion

The current study was aimed at providing a contribution to the understanding of the association of social factors and working conditions with fatal and non-fatal accidents at work across Europe. The study shows a moderate strength and quantity of associations of social and working conditions variables to accidents at work.

The correlation analysis between social and occupational dimensions showed the salience of peoples' perceived helpfulness, subjective general health, peoples' perceived trustworthiness, the trustworthiness of the legal system, the level of satisfaction with life as a whole, experiencing tiring or painful positions, working with electronic devices, recognition for work, organization motivated performance, job insecurity and prospects of finding a new job if needed. The social dimensions that are most noteworthy as determinants of working conditions are peoples' perceived helpfulness, subjective general health, peoples' perceived trustworthiness, the trustworthiness of the legal system, the level of satisfaction with life as a whole. In most countries encompassed in this study, fatal accidents at work are two to three orders of magnitude below non-fatal accidents of work; in many countries there is one fatal work accident for roughly every thousand non-fatal work accidents. Hence, the meager results of association and regression obtained for the fatal work accidents are understandable given that this is in most countries a "residual" phenomenon, where much progress has been made over the last decades. The most consistent determinants of fatal accidents found through the multiple approaches of association deployed was satisfaction with life as a whole. Determinants of non-fatal accidents consistently found through multiple approaches of association were relatively lower proportion of females in the population, higher incidence of lifting, propensity to disregard rules and a higher frequency of social gatherings.

Future research should focus on different levels of analysis, and exploring further implications for safety policy of the findings of the current study. Moreover, given the existence of longitudinal data for accident data and for the working conditions and social surveys, it is feasible to explore the evolution of the associations, and as such ascertain their persistence over time, and provide a contribution to build more generalized models of the phenomena under study.

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Culture and Organizational Aspects

Are Safety Culture Assessments Really Necessary?

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Abstract. Since the introduction of the concept of culture in the safety domain, much effort has been put into its assessment. Such assessments are typically carried out to come to a diagnosis and, possibly, a culture improvement. While the relationship between culture and behavior remains ambiguous and the odds of steering a culture into a desirable direction are equally uncertain, the development process of culture might offer more solace. Skipping the assessment altogether, the process offers both cultural insight and opportunities to influence the culture more towards a culture for safety. To establish such a culture, it is important that people can voice their concerns and share information openly.

Keywords: Safety culture · Safety culture assessment · Safety culture development · Influencing safety culture · Humble inquiry

1 Introduction

If I am not mistaken, the term 'safety culture' was coined right after the nuclear disaster in Chernobyl. Overlooking all wrongs and trespasses surrounding the nuclear reactor in Ukraine, the investigating committee's only resort seemed to be to put the label 'culture' on the disaster's overall cause. Safety culture, that is. The rest is history. Safety culture was eventually embraced by the safety community at large and became a main entry in the safety professional's handbook. As I have stated elsewhere, although the marriage of safety with culture has been prolific, it is unfortunate nevertheless [1]. While safety definitely has a normative flavor attached to it, culture has not. That is, something (an activity, an installation) can be safe or unsafe, good or bad, but cultures never are; they are just, well, cultures.

This popularity of safety culture has led to an avalanche of papers on the topic, of what it is and what it is not, on how to assess it and how to order cultures on a ladder into safety heaven, mimicking a similar boom in the 80s on the topic of organizational culture. Understandably, much effort has been put into the assessment or measurement of safety culture, all under the heading of "You cannot manage what you can't measure". But is this really necessary? I truly wonder. Is culture really manageable, or measurable, for that matter? I will explore these two questions in this paper.

Firstly, I will discuss the relation between culture and behavior; this is not an undisputed fact but instead an empirical question. This relationship might be present but is ambiguous. Then I will turn to the assessment of culture. Assessing culture is not without

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problems and while the relationship with behavior is indefinite, the outcome of the assessment is questionable too. Does this render the concept of safety culture useless? I do not think so and I will explain why in the next section. The development of culture is a continuous process and taking this as a starting point, opportunities to influence it open up.

2 Culture and Behavior

The construct of culture is familiar terrain for sociologists and anthropologists, but for safety professionals it is still quite new and so they are not yet fully comfortable with it. This is because culture is invisible, it only shows through something else, like, for instance, behavior. The main assumption is, that the (visible) behavior is driven by an (invisible) force. This invisible force is culture. The comparison of culture with a natural force is not entirely unreasonable [2]; natural forces are equally invisible but evidently exert their influence. (Safety professionals know all about this, as many accidents are caused by the force of gravity.) However, whether some behavior is caused by an underlying culture cannot be stated beforehand, it is an empirical question. I will explain why, using Figs. 1 and 2.

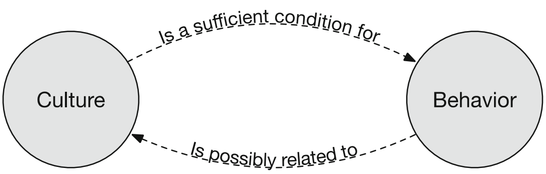

Fig. 1. The (ambiguous) relationship between culture and behavior and behavior and culture.

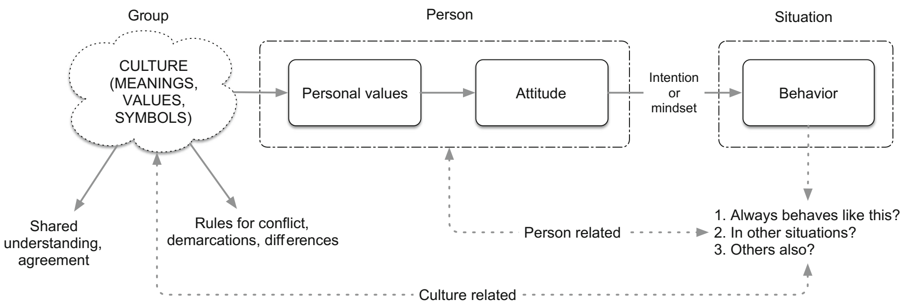

Fig. 2. The relationship between culture and behavior, mediated by personal and situational factors.

In Fig. 1, the ambiguous relationship between culture and behavior and, vice versa, behavior and culture is depicted. Neither one directly influences the other nor is influenced directly by the other. One could also state that neither one is a *necessary* condition for the other but, possibly, a *sufficient* one. Such vagueness is a nightmare for scientists but a real treasure-trove for consultants. What is more, their safety culture assessments profit from this vagueness, as they cannot seem to go wrong. Unfortunately, this also reflects negatively on the culture concept itself, as it has become a true 'God-of-the gaps', to explain missing links in our understanding of safe and unsafe behavior [1]. Nevertheless, we are not at a complete loss when considering the relationship between culture and behavior. Let us therefore turn to Fig. 2.

Culture exerts its influence through a person's personal values and attitudes, which translate themselves into an intention or mindset that may, or may not, materialize into behavior that is in harmony with the underlying culture. Throughout this chain, the (possible) influence of culture can diminish gradually. That is, a person can endorse a cultural value to a greater or lesser extent and also situational contexts may elicit or enforce counter-cultural behaviors. This is basically the culture–behavior chain.

Going backwards through this chain, when observing a person's behavior, an influence of culture can be put forward. The first question that should be asked, is, however, 'Does this person always behave like this?'. If not, the behavior might be accidental, or elicited or enforced by the situation this person finds himself (or herself) in. If the answer is affirmative, the follow-up question should be, 'Does this person behave like this in other situations?'. When this answer is negative, the behavior is probably determined by the situation and cultural causes can be dropped. However, when the answer is positive, the behavior is more probably related to the person, but other persons might behave in the same way. Therefore, a third question should be posed, 'Do others behave in a similar way?'. If yes, the cause of the behavior might be cultural and a further investigation into an actual cultural cause is warranted. Overall, looking at behavior and assuming cultural causes is tricky.

The backwards reasoning above is based on third-person (outsider) observations only. When involving people's own perceptions of their behavior and/or of an underlying culture, relationships become even more opaque. Schein's culture model can explain this quite well. According to Schein, an (organizational) culture consists of a core, surrounded by two layers. The *core* is the essence of the culture and mostly invisible to outsiders. Insiders experience the core as self-evident and self-explanatory, they cannot see things otherwise. When asked about their culture, they will *espouse* the things they think they need to say or are supposed to say: strategies, intentions, ambitions, and so on. This is also what outsiders first hear about a culture. Furthermore, what outsiders actually experience is even more remote from the core, the outer layer. Schein calls these experiences *artifacts*, the culture's observables [3]. The point is, what can be seen or heard about a culture, does not have to be in line with the culture's core. Moreover, insider's opinions about their culture are equally unreliable and need to be processed further (Schein talks about deciphering) to expose actual underlying cultural assumptions.

Back in the 80s, culture had already been imported into management science. At the time, (management) researchers wondered why some companies were more successful than others. A possible explanation was found in the company culture, also called organizational culture. Not only that, national culture was called into play, too. That is, both national culture and organizational could contribute to a company's success, or so the reasoning went. During that time, Hofstede's research on national cultures became popular also [4, 5]. Not without reason, as Hofstede's 4D-model is highly attractive because of its sheer simplicity. According to Hofstede, countries can be projected into this 4D-space based on their scores on each of the model's four dimensions: power distance, uncertainty avoidance, individualism (or collectivism) and masculinity (or femininity). That is, nations can be ordered based on the assumed power relations between people in the country, their overall preference for rules and structure, the importance of the (in) group versus the individual and the extent to which male (assertiveness, competitiveness) or female (mutual care, consensus) attributes are stressed in daily life.

While Hofstede's model was taken onboard by many management scientists and also managers, anthropologists did not care for it [6, 7]. For one thing, many do not really endorse 'national cultures', for another, they rather submerge themselves into a culture than send out questionnaires. This distinction between epistemologies is important and has been the cause of heated debates in the 80s and beyond. The distinction basically boils down to the research approach; whether culture is studied top-down (etic) or theory-driven, or bottom-up (emic) or data-driven.

3 Assessing Culture: Emic and Etic Approaches

Emic or data-driven research (emic) does not commence with a particular notion of how culture(s) are organized or 'dimensionized'. Put in other words, there is no standardized instrument to 'measure' culture with. A researcher studies a culture on its own merits, on its own achievements, on its own givens. (S)he starts from 'scratch' and works her (or his) way upwards towards a theory of the culture under study. The data collected are generally qualitative and the result is a rich description of a culture.

In contrast, an etic approach works from theory; a theory that describes what matters in (all) cultures and which provides a standardized instrument with which to 'measure' these generic aspects in a particular culture. Such measurements are typically obtained using a standard measurement scale, like a five- or seven-point Likert-scale; the latter scale measures endorsement on an x-point scale. This also means the data are quantitative. Hofstede's 4D-model is a typical example of an etic approach.

It is hard to reconcile both approaches. Moreover, both approaches seem to have merit, as all cultures will be somehow unique, although they will have coped with similar or comparable issues. In an etic approach, uniqueness will be reflected in unique scores on common dimensions, whereas in an emic approach, no common dimensions exist initially, although they might surface in the end.

Safety culture assessments need to apply an etic approach eventually, as only this approach provides a common framework to measure and compare (safety) cultures with. This means that safety cultures will not be judged on their own merits. They are either good, or not so good, or something in between. And safety heaven is the ultimate goal, whatever that may be.[1]

In much culture research the emphasis is on data collection, a description of the culture, and a diagnosis, i.e., pointing out relatively (strong and) weak points. Another way of making a culture assessment is comparing the description of a culture with a particular (safety) cultural norm; for instance, the safety culture requirements for organizations handling nuclear sources provided by the International Atomic Energy Agency (IAEA) [9] or the Institute of Nuclear Power Operations (INPO) [10]. Such requirements are often based on expert opinions about what is good or bad for nuclear safety. Please note the different types of knowledge required for such an enterprise, descriptive (assessment) and prescriptive (guidance).

Overall, there are five types of knowledge, which can be ordered in terms of relative complexity [11]. These types are:

1. Descriptive knowledge (knowledge describing a phenomenon);
2. Explanatory knowledge (kn. that describes causes and consequences);
3. Predictive knowledge (kn. making predictions possible);
4. Evaluative knowledge (kn. providing a basis for judgements, decisions);
5. Prescriptive knowledge (kn. to support well-founded advice or guidance).

Importantly, knowledge higher up in the hierarchy requires (established, well-founded) knowledge from a lower level. However, with regard to culture, much of what we know is still at the descriptive level. There is very little established knowledge beyond explanatory knowledge and even that is based mostly on argumentation, not on empirical research. Put in other words, there is very little evidence, if any, that the safety culture that is aimed for in some approaches, is as safe as it is assumed to be.

Due to the very nature of the concept, culture remains a highly descriptive phenomenon that has to be assessed indirectly through observations, statements, attitudes and perceptions. Instead of focusing on the assessment, the development of culture provides another handle to work with safety culture. This development is explored in the next section.

4 The Development of Culture

Culture is not a static notion, it actually develops continuously. Of course, the speed of this development is different at different levels of culture. National cultures (do they actually exist?) develop more slowly than organizational cultures, or cultures of smaller groups. Instead of focusing on the assessment of culture, organizations are better advised to 'work' with their culture. Please note the use of the verb 'work'; I specifically use the verb to 'work', not to 'change'. Changing comes close to 'manipulating', which is perhaps what managers want, but which is also unethical.

[1] In some approaches, like, for instance, Hearts & Minds (see: http://heartsandminds.energyinst.org/), high-reliable organizing (HRO) is considered to be the ultimate goal. HRO has been proposed as a solution against 'normal accidents'; major accidents that are bound to happen in tightly-coupled, hazardous systems [8].

The model of the development of culture will explain way; the model can be described using five distinct steps (Fig. 3) [12]:

1. Understanding
2. Exchanging
3. Formalizing
4. Transmitting
5. Reinforcing

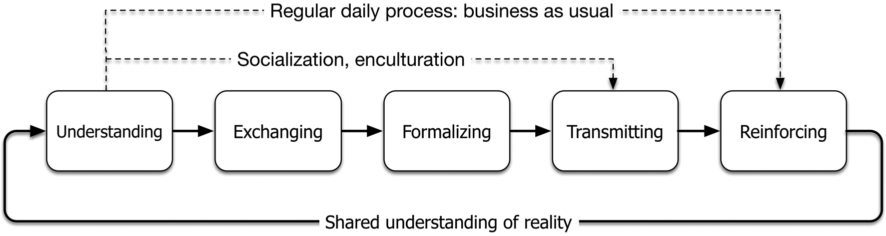

Fig. 3. The development of (safety) culture

The world does not speak for itself. Although this statement does not seem obvious, it is important to understand. The reason why the world usually does make sense is in part due to the fact that groups of people share some common understandings about the world that surrounds them. Part of this shared understanding is what we call culture [13]. Take, for example, a plastic bottle of water.[2] We all know what it is, what might be in it and what should be done with it. But how do we know this? Because somebody once told us, or showed us. However, someone who has never seen a plastic bottle, might not have a clue what is in it, or what to do with it.

Furthermore, having a similar understanding of a plastic bottle does not mean we attach a similar meaning to it. For example, a chemist sees a product of various chemical reactions and admires its strength or transparency. An activist, on the other hand, sees a reprehensible throw-away object of our consumer society and thinks with horror about the huge amount of plastic floating somewhere on the Pacific. And so on. The point is, that objects or actions or any other observable do not speak for themselves, do not have meaning or significance of their own. We continuously provide meaning to the surrounding world and many of these meanings are established in a culture. Step 1 in Fig. 3 above, is exactly about this, (trying to) understand the surrounding world by giving meaning to it. This is an individual activity that people carry out all the time.

However, people live and work together. Because of this, common meanings need to be established, otherwise confusion would be abounding. Such common meanings are established through human exchanges and interactions (Step 2). These interactions lead to agreements, disagreements, conflicts, and so on. Agreements will define of what is called the ‘shared understanding’, the common ground, the culture. Disagreements

[2] I borrowed this example from social constructivist Kenneth Gergen; see his full lecture on Youtube: https://www.youtube.com/watch?v=-AsKFFX9Ib0.

will delineate the borders of the culture. Conflicts might lead to separation and subcultures. Or the conflict continues within the culture as an agreement, "Let's agree to disagree", or a taboo that is left alone.

The agreement that is established eventually (or not) in this step has to be based on a full exchange, that is, it has to be truly open and evenly balanced between the parties engaging in the exchange. If not, the agreement is either not based on all information available (people are holding information back) or it is enforced (one party is actually imposing her or his view onto the other). Ideally, this exchange is based on 'Humble inquiry', or so Schein argues. Humble inquiry is an attitude practiced in communication that is aimed at a genuine interest in the other party's viewpoint [14].

People might recognize Step 1, but do not experience the exchange of Step 2. Obviously, within an existing culture there are already many agreements established, otherwise it would not be a culture. An exchange about meanings usually is not necessary, or even desirable. Instead, by interpreting an object or action as intended within the culture, people actually reinforce its intended (cultural) meaning. That is, they skip Steps 2 through 4 in Fig. 3 above, and immediately arrive at Step 5, Reinforcing. Step 2 might become active when no common meaning has been established yet, which might show in confusion, in a dilemma or a in conflict.

After a common agreement has been reached, one typically observes that such agreement continues as a sort of rule or standard. This rule might be written up as a law or procedure, but it can also live on as an 'unwritten' rule. Put in other words, one could say that the agreement has been formalized (Step 3). Formalization can become even more formal, which implies that the rule or standard has been institutionalized. This means that the rule functions as a formal standard or norm for the people in the culture. People are supposed to comply with it.

The advantage of written rules and standards is that they can be transmitted to others, to newcomers, for instance. This is the formal way. Within culture, part of the learning of the rules takes place informally. Through so-called socialization processes, newcomers are 'enculturated' (Step 4).

As already stated above, much of our actions within a culture are aimed at reinforcement (Step 5) rather than going through the more tedious process of negotiation of meanings and understandings. Furthermore, while agreeing about a tangible world is perhaps less demanding, finding common ground for intangibles is definitely far more complex. This is where safety and risk come in. Like risk, safety is intangible. Although people can develop norms and standards for safety measures and calculate risks associated with these, safety and risk are also experience-based, that is, they are informed by feelings and emotions [15]. This is where things become muddy and confusion, dilemmas and conflicts can arise.

The development process described above is a 'natural' process; it takes place continuously, whether we want it or not. An assessment of this process for the purpose of measurement seems therefore useless. Moreover, the outcome of this process is highly unpredictable, as it depends on the composition of the group, their tasks and the situation they find themselves in. However, the outcome is something that works for this group and when they have established it, they are disinclined to give it up. That is why cultures are so hard to influence. That is also why cultures are neither good nor bad; culture provides the common ground onto which its members can accomplish something together.

5 Influencing (Safety) Culture

A model like the one depicted in Fig. 3, provides some possible handles to influence this development process. In the end, that is the main reason why, for instance, safety professionals bother about culture at all. Given the fact that the assessment of culture is both cumbersome and descriptive, it raises the question of the actual use of such assessments. And when a culture finally has been carefully described, nudging a culture into a desirable direction is yet another challenge, which is improbable to succeed in the way intended, again due to the nature of the concept of culture and its ambiguous relationship with what can be observed. An alternative to this 'gap-analysis' approach is warranted. It goes as follows.

First of all, members of a culture (insiders) are best-equipped to truly understand their own culture, to understand what is really going on and why. Instead of explaining their cultural core to outsiders, they can better make it explicit to themselves. If possible, they can explain to themselves where their cultural assumptions initially come from. By revealing their shared assumptions, they will also discover how these assumptions work out in daily practice and what their effect on safety might be. Finally, when a cultural assumption has a negative impact on safety, insiders can work out means to influence this assumption, or to moderate it. This, of course, sounds easier than it is, but let us take a look at Fig. 3 anew and see how it can assist in influencing a particular cultural assumption.

Step 1 of Fig. 3 is concerned with understanding, with giving meaning to the surrounding world. Perhaps shared meanings around the safety of some activities, measures, or objects (installations) are not fully in line with the actual risks involved. This could be revealed through recurring incidents or accidents, or because workers have conflicting practices as they understand of conditions or situations in a different way. Harmonizing the way they understand of the situation might be therefore desirable. This is often done through communication or, more specifically, risk communication. The particular type of risk communication involved is called 'care communication', that is, 'communication about risks for which the danger and the way to manage it have already been well-determined through scientific research that is accepted by most of the [people]' [16]. Setting up an effective (care) communication strategy is well-established but specialized work. It is a typical top-down approach, but the target group is usually involved [17].

However, while culture is about assumptions and understandings shared by a group, to establish such shared understandings Step 2 (Exchanging) is mandatory. Here, the nature of the exchange is crucial; as stated above, it should be two-way, open and based on genuine interest and respect [14]. Only then, valid information can flow to and fro and when agreement is reached, it is based on shared, pertinent information. Again, this sounds easier than it is, and somebody like Chris Argyris has spent much of his career writing about this challenging process, which is also part of what is known as 'organizational learning' [18]. Importantly, the people that engage in Step 2, should be well-informed, otherwise the exchange is not based on valid information and the outcome is biased or distorted. This also highlights the importance of the 'care communication' of Step 1.

The first two steps are decisive for the rest of the process. Formalization should be based on true consensus, otherwise group members will not adhere to what has been formalized. Again, involving the targeted group members in the process of formalization is highly desirable and can be used as intervention measure for this step.

When disseminating cultural assumptions, one should not only consider formal education and training as channels but also group socialization processes. When newcomers are introduced to the group, they are much influenced by these processes. Putting real effort in socialization and joining newcomers with, for instance, 'safety buddies', experienced group members that embrace its (safety) cultural values, will obviously help them understanding the local (safety) culture [19].

As already stated above, the regular daily process runs from Step 1 (Sensemaking) to Step 5 (Reinforcing). This is because people's daily reality already makes sense through many established cultural meanings. However, this is also the downside, as these meanings can be misinformed (not based on all or wrong information) or outdated (the situation has changed drastically), and, hence, not supporting safety anymore. Keeping silent in such cases, simply means agreement.[3] However, going against the grain of consensus is often not easy, which brings us back at Step 2 (Exchanging). Establishing an environment where people can openly voice their concerns or disagree with current practices is key to creating a culture for safety; I prefer this term rather than safety culture, as the latter invites to reification.

The development process of culture is a natural and continuous process. Its content is determined by how people understand their surroundings. To establish a culture for safety, safety should be embedded in this process. In doing so, safety will gain more meaning and depth in the organization up to the effect that safety becomes a value. It will be that safety still has to compete with other organizational values, yet it will not function as an afterthought anymore, something that has been stapled on, simply because it is required.

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[3] As in the Latin proverb *Qui tacet consentire videtur, ubi loqui debuit ac potuit* (He who is silent, but should have spoken and was able to, is taken to agree).

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Strategically Developing a Resilient Safety Culture: Organizational Mindfulness and Mindful Organizing

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Abstract. The idea that an organizational workforce as a collective can have the attribute of being 'collectively mindful' points towards a readiness to respond through stable cognitive processes and variability in actions which are needed to maintain system functioning and manage system fluctuations when the unexpected happens. This paper reviews recent theory and research on the concepts of Organizational Mindfulness and Mindful Organizing with a view to imparting understanding on how the collective workforce plays a key role in the management of the unexpected by using the five principles of organizational collective mindfulness. Suggestions for strategically enhancing these organizational mindfulness concepts are discussed to enable enhancement of an organizational resilience safety culture.

Keywords: Organizational resilience · Organizational mindfulness · Mindful organizing · Strategic management strategy · Culture

1 Introduction

The idea that an organizational workforce as a collective can have the attribute of being 'collectively mindful' sprung out of the theory on High Reliability Organizations (HRO) [1]. These high hazard organizations are focused on being ready for the unexpected with strategic efforts directed towards an anticipation and readiness to respond through stable workforce cognitive processes and variability in workforce actions, which maintains system functioning and manages system fluctuations when the unexpected happens. Organizations outside of the HRO status are increasing recognizing the importance of being resilient in the face of unknown and unexpected events and acknowledge that they must strive to be able to respond effectively to system fluctuations. Organizational resilience is discussed here with a view to both instilling current theory and modelling on the subject matter, and then proposing some insights around how this concept might be strategically enhanced as part of wider organizational strategy.

Organizational resilience is understood to be the ability of an organization to respond to operating fluctuations and to successfully manage the unexpected when it occurs. This

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becomes a paradox between system stability versus system renewal and results in a requirement for skilled management of a complex dynamic relationship between maintaining order and growth, and renewal after disorder [2].

The previously mentioned writing by Weick, Sutcliffe and Obstfeld [1] was early in the assimilation of HRO theory into more mainstream organizational theory, but pointed towards the value of understanding how HRO's "embody processes of mindfulness that suppress inertia" (p. 31) to enable organizational system fluctuations to be successfully managed. In studying HROs it was found that the key to their effectiveness appeared to be the close relationship between the workforce and a repertoire of actions conducted by the workforce, where a variety of action was required in order to maintain the stability and resilience of the organization as a whole.

This variety of workforce actions represents a movement away from ridged and prescriptive processes and is necessary to enabled system fluctuations to be effectively managed by the workforce at crucial times. At the group level, it is expected that workers would be capable of taking notice of new or developing variables within the system, in a sense increasing the organizational adeptness to become aware of and deal with changing workplace issues as they arise. In essence workers become collectively 'mindful' of what is happening within the system in which they operate [1] in order to respond in a way that manages system and workplace instabilities as they arise, with a view to preventing any escalation into more serious occurrences.

Of importance was the notion that two elements in fact come into play, being a combination of stable cognitive processes and variations in action patterns, which enable the more successful HROs to manage unexpected events effectively [1, 3]. The ability of organizations to become resilient became anchored into these cognitive process of the workforce whose actions needed to be flexible, responsive and at the same time focused on the best possible outcomes in the face of failures which may have severe consequences.

The concept of organizational resilience is usually seen as a strategically driven initiative by top management, often being associated with internal safety and risk management endeavours and expands to pre-emptive organizational tragedy management strategies around positive organizing [4]. HRO theory proposed that at the group and wider organizational mindfulness level, five principles grounded around cognitive inquiry and interpretative capabilities for action, make up what has become called 'collective mindfulness' [1], the necessary ingredient in organizational resilience. The now widely recognized principles of collective mindfulness are (1) Preoccupation with Failure; (2) Reluctance to Simplify, (3) Sensitivity to Operations, (4) Commitment to Resilience, and (5) Deference to Expertise [2]. These processes are also processes of mindful organizing and enable awareness, wisdom and reliability [4].

The first empirical validation of the five principles of organizational mindfulness was presented in 2011 by Ray, Baker and Plowman [5] who conducted research within business schools and measured the perceptions of organizational mindfulness based on worker's roles ranging from deans, associate deans, assistant deans down to department heads. Results showed that perceptions of organizational mindfulness were positivity associated to proximity of role to the top of the organization. Meaning, the higher one is in the organizational hierarchal structure the higher one's perception of organizational mindfulness appeared to be. The results also acknowledged that worker's role within the organization is an important consideration, as it is linked to what is 'seen' within the organization, therefore those workers closest to the front line, have a very different view of the organization than those at the top, responsible for the strategic operations [5, 6].

The research being presented here was interested in exploring how strategic efforts should be directed if the desire is to increase collective mindfulness with a view to also enhancing an organization's resilience maturity. Of significance for enhancing organizational mindfulness culture are the notions that (1) shared perceptions of collective mindfulness vary across various workgroup levels, and (2) that perceptions of organizational mindfulness have been shown to be positively associated with proximity of role to the top of the organization.

2 Collective Mindfulness

Theory around organizational mindfulness progressed in 2012 to the development of a model [7] (see Fig. 1) spring boarded from the writing by Ray, Baker and Plowman [5] and which attempted to reconcile conceptual puzzles building up around the theory of collective mindfulness, particularly as to whether it is strategic, top-down and enduring [5] or focused on operations as bottom-up and fragile [7].

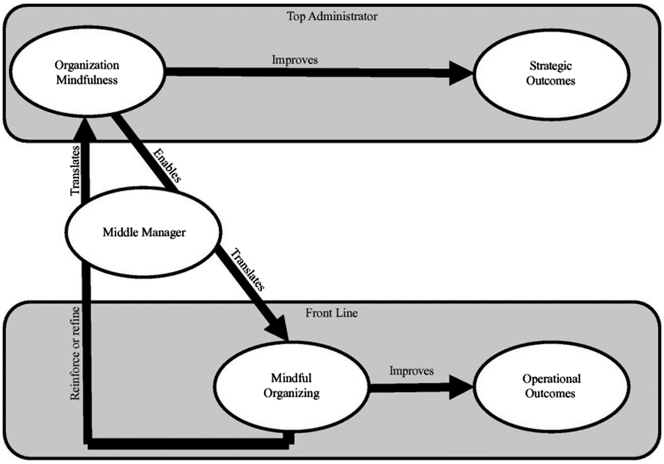

Fig. 1. Reconciling organizational mindfulness and mindful organizing

The model developed by Vogus and Sutcliffe [7] to reconcile the issues, suggests that two separate actions are in fact in play, that of 'organizational mindfulness' and 'mindful organizing', both of which are required to enable organizations to achieve improved levels of organizational mindfulness as a collective.

It proposed that two distinct mindfulness actions are undertaken within an organization by different levels of the workforce based on the roles that they perform. They postulate that there are inherent differences between top administrators who are performing more of a strategic ‘organizational mindfulness’ role compared to the front line workers who undertake a more ‘mindful organizing’ role, with middle managers playing an equally important translating and enabling role between the other two organizational levels, as seen in Fig. 1.

Weick’s [4] work which discusses positive organizing and organizational tragedy also supports a tripartite model by maintaining that positive organizing takes the form of respectful interaction at the workforce (micro) level, heedful interrelating at the intergroup (meso) level and mindful organizing at the organizational (macro) level (p. 215). More recent research by Reitzig and Maciejovsky [8] into corporate hierarchy and vertical information flows supports the role of middle managers as information conduits suggesting there is a “refined picture of the true role of middle managers within the strategy information process” (p. 1996) however it was also acknowledged that this information sharing role is not straightforward or without its challenges [8, 9].

3 Organizational Mindfulness - The Five Key Principles

Organizational mindfulness is described as the extent to which a particular organization is able to assess threats that may emerge and capture such detail so that they are able to respond quickly and reliably to prevent incidents or system failures [10]. Collective mindfulness is manifest in organizations by an ability to be sensitive to changes in the work environment, continuous updating of the way in which they think and perceive things and by appreciating the importance of context [3].

Research now supports the notion that collective mindfulness can be measured within mainstream organizations by assessing five principles [5, 7]. These five processes include (1) a Preoccupation with Failure, (2) Reluctance to Simplify, (3) Commitment to Resilience, (4) Sensitivity to Operations and (5) Deference to Expertise [10]. Organizations that have the ability to successfully combine these five principles, detailed in more depth below, are able to successfully detect and manage unexpected events and therefore enhance organizational resilience [1].

3.1 Principle 1 - Preoccupation with Failure

Principle 1 relates to the way that the organization and its workforce notice and deals with failures. Failures in this context is not necessarily large safety events but cover a range of issues including deviations, risks, bad news items, surprises, things out of context, near misses and errors [10]. A preoccupation with failure “is a pre-occupation with maintaining reliable performance … and reliable performance is a system issue” [10, p. 55]. Organizations that are mindful display an understanding that long periods of successful outcomes can breed complacency. Any small failure within the system is seen as a precursor for a larger issue at a later date and effort, attention and action is required to firstly notice small issues and then to take action to ensure they are not just the beginning of something bigger. For this reason, they are preoccupied with failure and are continually looking for lapses, errors and faults that may be precursors to potential failures [11]. It is these concerns about failure that are a quality that makes mindful organizations distinctly different. They have a tendency to analyze and become preoccupied with shortfalls that seldom occur. However, failure concern alone is not the only thing organizations need to focus on and sensitivity to variety is encompassed in principle 2.

3.2 Principle 2 - Reluctance to Simplify

Principle 2 focuses on the organization's ability to manage variation and identify signs that the unexpected is unfolding [10]. Successful HROs displayed a belief that work tasks and the environment are complex systems and as such, they are reluctant to simplify practices, procedures and interpretations [1]. They have a tendency to restrict simplifications enabling a greater number and variation in precautionary measures to be established and implemented [12]. Simplifications of the way in which interpretations are made of situations are considered high risk to HROs. They do not want their workers to just keep going ahead with tasks when their interpretation and intuition identify anomalies that may lead to dangerous situations [1]. HROs encourage their workforce to take the time to assess systems and double check processes even when they appear to be successful or when claims are made that they are successful. Procedures developed and practiced by HRO's are thorough, complex and formalized through documentation and systems that match the complexity of the environment and task [13]. They are also acutely sensitive to operations, which is elaborated on as principle 3.

3.3 Principle 3 - Sensitivity to Operations

A defining feature of a collectively mindful organization is that the front line operators display high levels of situational awareness and strive to understand what is happening in the present and they are always looking for what may happen in the future [11]. These front line operators at an individual and collective level develop an overall big picture of the organizations operations [3] enabling a prevention of accidents and failures through anticipation of future events [10].

3.4 Principle 4 - Commitment to Resilience

Mindful organizations that are successful in avoiding and preventing disabling occurrences are able to demonstrate a commitment to resilience by dealing *effectively* with errors and unexpected events. They are not disabled by such errors but rather are able to mobilize themselves in order to deal with them [1]. When HRO's are effective, they are able to develop anticipation and therefore prediction of potential dangers before they occur. When an unanticipated danger does occur these organization is able to initiate actions and responses to cope and rebound.

System reliability is a focus for HROs however, they also understand that reliability is tied to the concept that they must have a workforce that is able to investigate, learn and act without knowing in advance, what the initiating event will be. This is a capacity and mindset to be able to anticipate and then be flexible in recovery action repertoires to enable functioning to continue. It also requires quick feedback to ensure actions are resolving the unfolding issues; both learning from experience and the ability to question current actions is a fine balance in managing previously un-encountered failures. In these situations it helps to have the right people dealing with the issue as described in Principle 5.

3.5 Principle 5 - Deference to Expertise

The final principle in mindful organizing is deference to expertise [1, 10]. When operations are functioning normally there is an organizational hierarchical structure that defines roles and responsibilities including lines of communication and reporting. In emergencies however this organizational structure may be relinquished to enable the most experienced people to be the ones dealing with the problem.

Deference to expertise is a belief that experience and expertise must be applied to variations in normal functioning regardless of workforce hierarchical positions. It has been argued by critics of this final process of mindful organizing that in times of critical emergencies it is inevitable that decisions are going to be made by the front line operators on the ground because in these situations there may not be time to refer decisions up the chain of command [14].

4 Current Research Exploring Workforce Shared Perceptions

To examine further the concepts put forward thus far, research was conducted on the perceptions of collective mindfulness of both front line workers and middle managers as proposed by the Vogus and Sutcliffe model [7]. The focus was on measuring the perceptions across the five principles of organizational mindfulness to see if perception level was linked to role as suggested by Ray, Baker and Plowman [5] and whether the notions and model put forward by Vogus and Sutcliffe [7] could be elaborated on when enhancing organizational mindfulness culture.

In order to explore the principles of organizational mindfulness further five organizations in the marine industry in Queensland, Australia took part in a research project. These organizations represented commercial vessel tourism operators (n = 2), ship repair, construction and management (n = 2) and a hydraulics engineering company (n = 1). Ethics approval was obtained from the Central Queensland University's Low Risk Ethics Committee.

A total of 163 participants were surveyed with (n = 125) being front line workers and (n = 38) being in the manager/supervisor category. Participants were asked to rate their responses to 25 questions related to the five principles of collective mindfulness within their organization. To measure organizational mindfulness a Collective Mindfulness Survey (CMS) was developed for the research presented here. The CMS is a self-report measure made up of 25 questions with five questions covering each of the five principles of organizational mindfulness. Participants were asked to answer using a 5-point Likert scale with response options being (1) Always, (2) Often, (3) Sometimes, (4) Seldom and (5) Never. The CMS has good internal consistency, with a Cronbach alpha coefficient reported as .959, but the CMS is yet to be empirically validated.

4.1 Results

To compare the organizational mindfulness scores for middle managers and front line workers across the five principles of organizational mindfulness, a comparison of mean scores for both groups was conducted with an independent samples t-test using SPSS version 21. In all cases middle managers scored higher than front line workers (see Table 1) supporting previous research on this matter [5].

Table 1. Means, standard deviations for middle managers and front line workers across the 5 principles.

Principle	Role	Mean	Std. deviation
Preoccupation with failure score	Middle managers	23.00	2.30
	Front line workers	22.39	3.53
Reluctance to simplify score	Middle managers	20.49	3.10
	Front line workers	20.29	4.10
Sensitivity to operations score	Middle managers	20.46	3.53
	Front line workers	19.23	5.00
Commitment to resilience score	Middle managers	18.28	3.86
	Front line workers	17.37	5.54
Deference to expertise score	Middle manager	19.54	3.09
	Front line workers	18.30	5.18

Results therefore supported previous research that perceptions of the level of organizational mindfulness within an organization can be measured and tend to increase as one gets closer to the top of the organization [5].

5 Organizational Mindfulness Culture Discussion

Several questions on how to enhance organizational mindfulness culture still remain unanswered in this theoretical domain. These include whether enhancement will be achieved by focusing on a top-down processes or bottom-up processes [5] and whether increasing individual mindfulness would transfer to increased organizational mindfulness? Whilst individual mindfulness is not traditionally measured or associated with the five principles of organizational mindfulness, it has been found to be positively related to workplace safety, the more positive dimensions of personality, and reductions in human performance cognitive failures [15, 16]. In some respects it would be thought that enhancement of individual mindfulness would transfer to enhancement of workgroup mindfulness via workgroup interactions and would contribute to the 5 principles particularly around the ‘noticing’ of emergent system issues. These question have been suggested as areas where further applied research is required and point toward the future of organisational mindfulness and resilience research work. This may be little comfort for those wanting definitive answers now, but suggestions for organization culture enhancement can be offered based on what is already known, and are offered at this point.

Previous research, including the research presented here, has demonstrated that organizational mindfulness and its 5 principles can be measured including across various workgroups, and the results give organizations a starting point from which to understand the shared perceptions of their workforce. This information can point towards where differences and deficiencies across the five organizational mindfulness principles exist. Strategic efforts can then be directed towards those areas in need of enhancement.

Research results have also established that organizational mindfulness is perceived to be higher as worker roles get closure up the organizational hierarchical ladder towards more strategic positions. Critically thinking on the subject, is this the best outcome for organizational resilience? Should those at the top of the organization be perceiving the organization as more mindful than those further down, based on what is known about the cognitive and action system anchors which make up the five principles? Presented here is the view that organizations should be striving to inverse this trend and enhance the organizational mindfulness of front line workers in an effort to achieve increased organizational resilience maturity. Further consideration points to support this notion are therefore presented.

The model by Vogus and Sutcliffe [7] emphasizes the significance of the mindful organizing actions required of the front line workers to maintain operational outcomes. These are theoretically the cognitions and actions undertaken by this workforce and embedded within the five principles of organizational mindfulness. These front line workers are the collective workforce who are required to mindfully organize to accomplish these principles, of course with the help of middle managers who enable these workforce actions. Mindful organizing must incorporate the five principles of organizational mindfulness to a high level to achieve continued successful operational outcomes within complex and fluctuating systems and hence safeguard organizational resilience.

Whilst it is acknowledged that front line workers are conducting mindful organizing activities it is suggested that theoretically it would be desirable that their level of perception of collective mindfulness for the organization, should be equal to if not higher than those at other more senior levels further removed from the front line, where the operations take place. Timely and critical action response repertoires mostly fall into the domain of front line workers, who are closest to where the organizational operations are conducted and where system fluctuations are first noticed and felt.

It is therefore proposed that strategically, top administrators and managers, those responsible for improving organizational mindfulness strategic outcomes, should be striving to inverse the identified research trending and focus efforts on increasing their front line workers perceptions of organizational mindfulness.

Organizations of course, want and need top administrators who drive organizational resilience endeavours and who understand the role that organizational mindfulness plays in achieving this goal, but their view/perception of the organization is often a far cry from those at the front line, as previously discussed.

Of importance then is the recognition by top administrators (as suggested by the model) that operational outcomes are predominately the results of the workforce closest to the ‘action’, as they are the ones exposed to system fluctuations at the coal face on a daily basis. The front line workforce have a critical role to play and therefore, they importantly must be the ones who espouse collective mindful principles to the highest level within the organization for it to be truly resilient.

Middle managers no doubt play an important role too and are the “individuals who make decisions about how to implement the organization’s strategic objectives … interpret information and make it meaningful to those below them in the hierarchy who are responsible for technical activities… and see more and different aspects of rare and unusual events” [17, p. 912]. Mindful organizing has been widely recognized as a social sensemaking endeavor and the principles of mindful organizing show managers that reliability in dynamic contexts involves “a matter of consistency in checking, revalidating, decontextualizing and adapting as a perpetual process” [18, p. 223].

In examining organizational mindfulness from a systems leadership perspective [19] increased organizational mindful leadership at the middle management level could, in theory, transfuse in all directions permeating organizational mindfulness culture within the organization via its system wide interconnectedness.

In conclusion, levels of shared perceptions between workgroups should be understood via measurement (organizational mindfulness surveys) and areas of lower convergence identified. As the idea has been postulated that weak shared perceptions will affect mindful organizing activities, [20] an understanding of where these shared perceptions are weak, enables strategic mindfulness efforts to be enacted to increase the strength of shared perceptions.

Enhancing organizational mindfulness and resilience culture must lie in developing the five principles widely throughout the workforce, particularly towards the front line workers, with both top administrators and middle management supporting this workforce to become organizationally more mindful in the undertaking of their mindful organizing activities.

6 Summary

Presented here is recent research, theory and modelling around the concepts of organizational mindfulness and mindful organizing in relation to organizational resilience. Of particular interest was the development of a model proposed by Vogus and Sutcliffe [7] in order to reconcile how different workforce roles within an organization might lead to two distinct actions systems, one of ‘organizational mindfulness’ and one of ‘mindful organizing’ which could be explained across three workforce domains.

As well, as some food for thought around strategic enhancement of organizational resilience was advocated based on recent applied research. In particular, the research presented here examined further the perceptual differences of organizational mindfulness between front line workers and middle managers with a view to understanding if trending across the workforce supported previous research [5].

Previous research [5, 17] has also shown that organizational mindfulness can be inherently fragmented due to role specialization, e.g. operational v strategic and hence different perceptions of organizational mindfulness may logically exist depending on where one sits in the organization. Confirmed by the research conducted here was the notion that perceptions of levels of organizational mindfulness have been found to be perceived to be higher the closer one is to the top of the organization [5]. However the view point put forward here is that this may not strategically be a good thing for organizations wishing to achieve higher levels of organizational resilience and it is suggested that organizations generally try and balance or inverse these workforce hierarchal differences.

Well accepted is that for organizational mindfulness to produce both strategic and operational resilience it needs to operate across all organizational levels. It must be envisioned by top administrators, synchronized across levels by middle managers and translated into important workforce actions, particularly on the front line. Front line workers must be enabled to enhance mindful organizing actions by refining processes and routines based on the five principles and these need to be enabled by middle managers, translated to, and supported by top administrations as part of the wider strategic plan.

Top administrators, who are responsible for directing strategic leadership efforts towards enhancing both collective mindfulness and mindful organizing maturity, are now able to measure and assess this concept within the organization, and use this information to improve both strategic and operational outcomes, particularly around organizational resilience and managing the unexpected.

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Development and Initial Testing of a Regulatory Body Safety Culture Perception Survey

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Abstract. Regulator safety culture is a relatively new area of investigation, even though deficiencies in regulatory oversight have been identified in a number of public inquiries (e.g., Piper Alpha, Deep Water Horizon). More recently, the International Atomic Energy Agency's report into the Fukushima disaster specifically identified the need for regulatory bodies to have a positive safety culture. While there are clear parallels between duty holder safety culture and regulator safety culture there are also likely to be differences. The present study adopted a two-phase approach that (1) used literature review and interviews with 13 safety culture experts to develop a framework on regulator safety culture and (2) used leanings from Study 1 in combination with items developed by a safety culture working group to develop and evaluate a regulator safety culture survey. The importance of regulator safety culture incites the need to develop valid and reliable tools to assess this construct.

Keywords: Regulator · Safety culture · Oversight · Perception survey · Framework

1 Introduction

Safety culture is well supported as a critical factor that impacts organizational safety. Across industries such as nuclear and oil and gas, investigation reports of major accidents have consistently identified cultural threats as contributing factors [1–4]. Regulatory agencies are tasked with overseeing the safe operation of licensees. Thus, ensuring that a regulator's oversight approach fosters continuous development of licensee safety culture is a critical factor in fulfilling the regulator's mandate of ensuring safe operation.

The Fukushima Daiichi accident report appears to be one of the first accident investigations to identify regulator safety culture as a contributing factor in accident causation. This report highlighted the importance of regulator's having legal authority, technical competence, and a strong safety culture in order to effectively oversee the safety of licensees [2]. While safety culture frameworks and strategies for assessment for high-risk organizations have gained popularity over the last decade, representation

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and assessment of regulator safety culture has not been well established. The intangible nature of safety culture has long resulted in debate regarding representation and best practices for assessment. Conceivably, identifying and assessing the culture of the regulator that best promotes safety culture in its licensees is not without challenge and has likely contributed to the limited scientific research in this area. Combined with the growing acknowledgment of importance, this paucity of research prompted the following two-phased study to first, develop a framework of regulator safety culture, and second, develop and evaluate a regulator safety culture perception survey.

1.1 Regulator Safety Culture

With the exception of a case study aiming to define the organizational culture of a Finish regulator [5], only a small number of works have begun to identify frameworks for regulatory oversight thought to best influence operator safety culture (e.g., [6, 7]).

Bernard [6] aimed to develop a model representing safety culture oversight in order to promote the development of assessment tools and foster regulator's "safety culture observation" [6]. In short, Bernard's work focuses on identifying a practical approach to identify signals of licensee's safety culture functioning in order to shape appropriate regulatory response [6]. Most closely aligned with the intent of this research is the guidance document published by the Organisation for Economic Co-Operation and Development (OECD) on safety culture of an effective nuclear regulatory body. This work combines findings from discussions with members of a Senior-level Task Group on the Safety Culture of an Effective Nuclear Regulatory Body, as well as the outcomes from an NEA Workshop on Challenges and Enhancements to the Safety Culture of the Regulatory Body, to establish principles and attributes for the safety culture of an effective regulatory body. The present study aims to investigate this phenomenon using a broader lens by utilizing safety culture expertise from professionals with various industry backgrounds.

It should be noted that while this paper uses the term "regulator safety culture," debate exists concerning the most appropriate term for this concept. This debate is partially attributable to the various definitions of safety culture; one review identified 18 definitions of safety culture and climate, demonstrating the variability in how this construct is described [7]. Unlike high-risk organizations whereby safety culture impacts safety outcomes of that organization, the safety culture of the regulator represents the cultural features of regulatory functioning that influence the safety culture of licensees. Thus, the definition of regulator safety culture must appropriately represent this unique context and degree of separation between cultural functioning and safety outcomes. Considering this, the following definition of safety culture is used in defining regulator safety culture:

> "…that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance" [8].

Using this definition, regulator safety culture may be more easily assumed to include the values, attitudes, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, the regulator's oversight approach.

2 Study 1: Framework Development

2.1 Purpose

The purpose of Study 1 is to use findings from the aforementioned publications on regulator safety culture in combination with expert opinion to produce a framework representing regulator safety culture.

2.2 Method

Materials and Measures. Thirteen one-on-one semi-structured interviews were conducted on different days over the course of four months. Participants were provided an informed consent form detailing voluntary participation, study content, and confidentiality of the data. Interviews were conducted by telephone and recorded using computer audio software. Written notes were recorded using a laptop computer.

Procedure and Participants. A participant solicitation list was compiled by identifying safety culture experts through publications, practice, and asking safety professionals for recommendation of names. Participants were contacted by e-mail by the researchers and arrangements were made to complete a telephone interview. Thirteen participants (23% female) were recruited for volunteer participation. Participants were from around the world and recognized for having expertise in safety culture. Participants identified as being employed as academics or practitioners in a variety of industries. Upon completion of the interview by the second author, audio recordings were sent to a transcriptionist. On return, the second author ensured any identifying information was removed from reports and supplied the documents to the first author. This step was completed due to the first author's pre-existing relationship with many participants. Data saturation was tested and met following principles outlined by Francis et al. [9]. The proposed study involved no direct threat or risks to participants.

2.3 Study 1 Results and Discussion

The purpose of Study 1 was to develop a framework of regulator safety culture by interviewing professionals in a range of industries whom have expert knowledge of safety culture. Results from the interviews included representation of the construct of regulator safety culture and highlighted the importance of investigating this construct as well as best practices for assessment.

Table 1. Description of the 5 themes representing regulator safety culture.

Theme	Description
Leadership commitment to creating a positive safety culture	Leaders' shared value to ensure the regulator: (a) adopts a proactive approach to the development of industry safety, (b) is committed to continuous learning and self-development, (c) maintains ethical practice, and (d) is transparent in all activities.
Proactive, risk informed and flexible approach	A shared value for continuous improvement shaped by research, collaboration with external agencies, and a coaching style of management that demonstrates human value (versus a compliance-only focus). A willingness to engage in prescriptive versus performance approaches as needed based on risk, the ability to guide licensees without overstepping, and maintaining a belief that behavior is shaped through leadership characterized by constructive feedback and contingent reward.
Continuous learning and self-improvement	A shared value for continuous learning and self-development. Includes a shared value for adequate competency within the regulator, openness to learning, and maintaining an awareness of the limits of competence.
Unwavering ethical standards	A shared value for upholding ethical standards. Maintaining a value for professionalism in all conduct within the regulator and in work with external agencies (licensees, stakeholder organizations, government). Unwavering ethical standards in the face of external influences (e.g., political pressures, pressures from societal culture, threat of residential safety or security). Abiding by the same standards set for licensees and maintaining fair expectations and independence.
Transparency through communication	A shared value for communicating internal processes to keep all parties (regulator employees, licensees, public, government, stakeholders) informed on regulatory decision-making and action. Ability to communicate with external parties in a rational and scientific manner and convey sensitive regulatory processes in a manner that appropriately relays the information and does not foster the development of premature conclusions.

Participants' descriptions of regulator safety culture were aggregated to identify the five themes represented in Table 1. A brief synopsis regarding the essence of each theme is also provided. The five themes represent the notion of employees' shared values. Examples of participant descriptions supporting these themes can be found in Appendix A.

A small number of participants stated that regulator safety culture is equivalent to safety culture of licensees, and thus, an already established framework could be used to represent regulator safety culture. Others proposed that because the regulator functions to ensure safety of the industry and is not a high-risk organization, safety culture manifests differently, and therefore requires a framework unique to the regulating authority. As discussed in Sect. 1.1, the authors contend that the unique nature of regulator safety culture constitutes the development of a new framework to appropriately represent this concept. The five themes identified were carefully constructed from participant suggestions, including statements of themes and comparison with existing frameworks (e.g., [6, 7]).

There was unanimous agreement among participants regarding the merit of assessing regulator safety culture. Participants stated that assessment is critical to the development of industry safety, and one participant claimed that in the wake of the Fukushima disaster, there exists an obligation to assess safety culture to prevent similar accidents from occurring. A majority of participants agreed that a multi-method approach whereby data is triangulated would best support cultural measurement. Subsequently, these findings provided preliminary insight regarding a framework of regulator safety culture and contributed to Study 2: the development of a method for assessment.

3 Study 2: Evaluating a Perception Survey

3.1 Survey Development

Building on the findings from Study 1, Study 2 evaluated a survey that was developed by an International Atomic Energy Agency (IAEA) working group on regulatory safety culture. It is important to note that the IAEA subscribe to the use of a multi-method approach in order to assess safety culture. The development of a survey is to contribute to this multi-method approach and is not designed to be used as a standalone assessment tool.

The IAEA working group on safety culture developed the survey over a four day period. The working group reviewed the results from the interviews in Study 1, the Nuclear Energy Agency (NEA) document on regulator safety culture [10] and the IAEA model on safety culture [1]. The working group expanded the original five themes described in Study 1 to 11 dimensions (see Table 2). Once the 11 dimensions were established, the working group broke up into smaller groups where each sub-group generated survey items for a different regulator safety culture dimension. Following item generation, a different group reviewed and refined the items generated for the dimensions. Finally, the working group as a whole reviewed each sets of items until a final set of 144 items was created.

3.2 Method

Materials and Measures. One hundred and forty-four items were drafted and categorized into 11 proposed dimensions of regulator safety culture: (1) leadership (e.g., Leaders behave as role models for a positive safety culture), (2) psychological safety

Table 2. Mapping the 11 dimensions on the 5 themes of regulator safety culture.

Themes	Dimensions
Leadership commitment to creating a positive safety culture	Leadership
	Responsibility and accountability
	Independence of the regulator
Proactive, risk informed and flexible approach	Systemic regulatory approach
	Decision making
Continuous learning and self-improvement	Continuous learning, improvement and competence
	Questioning attitude
Unwavering ethical standards	Ethics and moral courage
	Psychological safety
Transparency through communication	Openness, transparency, external cooperation and communication
	Inter-disciplinary internal cooperation

(e.g., My organization is free of intimidation), (3) continuous learning, improvement and competence (e.g., We learn from other relevant organizations), (4) ethics and moral courage (e.g., It is easy to raise ethical concerns without fear of retaliation), (5) openness, transparency, external cooperation and communication (e.g., My organization strives to be transparent with all interested parties), (6) independence of the regulator (e.g., We don't allow external influence to compromise safety), (7) responsibility and accountability (e.g., People are held accountable for their work), (8) systemic regulatory approach (e.g., Our interactions with the licensees is based on mutual respect), (9) decision making (e.g., Safety is the overriding priority when decisions are made), (10) questioning attitude (e.g., Leaders solicit challenges to their assumptions), and (11) inter-disciplinary internal cooperation (e.g., Team members share accountability for their work).

Procedure and Participants. Following item creation, the 144 items were sent to subject matter experts (SMEs). Two samples of participants were recruited on a volunteer basis through e-mail invitation. Sample 1 comprised of 14 participants with expertise in (regulatory) safety culture. The SMEs were asked to evaluate (1) how closely each scale item is related to the specific safety culture element that it is intended to assess, (2) the clarity of each scale item, and (3) the importance of each scale item for safety culture each on a 3-point scale. All SMEs had professional expertise in regulatory bodies and their culture. Sample 2 was comprised of 18 employees of nuclear regulatory agencies (similar to the target population for the scale). These participants were asked to evaluate the importance of each scale item for safety culture on a 5-point scale.

Once recruited, participants were directed to an online consent form and prompted to respond with "Yes, I agree and wish to participate" to proceed with the survey. If consent was obtained, participants began the study.

3.3 Study 2 Results and Discussion

Upon initial inspection of the scale items, all items in the 11 dimensions were rated favorably overall by both the SME sample and the regulator employee sample (see example in Table 3 using the Leadership dimension). Specifically, Sample 1 ratings had means of 2.70 (SD = .22; how closely each scale item is related to the specific safety culture element that it is intended to assess), 2.70 (SD = .19; the clarity of each scale item), and 2.79 (SD = .17; the importance of each scale item for safety culture) on a 3-point scale. Sample 1 ratings had an overall mean of 2.76 on a 3-point scale (SD = .15) across all three rating scales. Sample 2 ratings had an overall mean of 4.50 on a 5-point scale (SD = .20).

In order to shorten the scale to a more reasonable number of items for future use, the scale items were rank ordered. Specifically, the mean responses for each of the three questions in the Sample 1 data and the single question in Sample 2 were calculated for each item. The means of the three questions in the Sample 1 data were then averaged to create an overall mean rating. Ranks were created for the overall mean of Sample 1 as well as for the mean of Sample 2. Finally, the Sample 1 and Sample 2 ranks were averaged together to create an overall rank. In order to reduce the scale items, we retained half of the items in each dimension with the highest overall rank (highlighted in bold in Table 3). This process resulted in reducing the total amount of scale items from 144 to 71.

The purpose of Study 2 was to evaluate a working group's development and evaluation of a perception survey. The initial scale contained 144 items based on 11 dimensions (i.e. (1) leadership, (2) psychological safety, (3) continuous learning, improvement and competence, (4) ethics and moral courage, (5) openness, transparency, external cooperation and communication, (6) independence of the regulator, (7) responsibility and accountability, (8) systemic regulatory approach, (9) decision making, (10) questioning attitude, and (11) inter-disciplinary internal cooperation). These items were reviewed by experts and employees of nuclear regulatory agencies. These results were used to reduce the scale to 71 items.

Interestingly all of the scale items (even those we removed) were rated favorably by both those with an expertise in safety culture and employees of nuclear regulatory agencies. This suggests that by adopting a systematic approach an expert working group can develop effective perception survey items. The next step is to examine the psychometric properties of the reduced scale by surveying a convenience sample of staff from nuclear regulators.

4 Summary and Concluding Discussion

The present study aimed to establish a framework of regulator safety culture and evaluate a perception survey based on this construct. As described in Study 1, five themes were identified from safety culture experts' descriptions of regulator safety culture: (1) leadership commitment to creating a positive safety culture, (2) proactive, risk informed and flexible approach, (3) continuous learning and self-improvement, (4) unwavering ethical standards, and (5) transparency through communication.

Table 3. Example of scale item ranking process using the leadership dimension of the scale. Note: 1 = how closely item is related to intended safety culture dimension 2 = the clarity of each scale item, and 3 = the importance of each scale item for safety culture.

Item	Sample 1					Sample 2		Overall rank
	1	2	3	Mean	Rank	Mean	Rank	
1. Leaders behave as role models for a positive safety culture	**3**	**2.86**	**2.93**	**2.93**	**1.5**	**5.00**	**1**	**1.25**
13. Our management takes clear responsibility for their own actions and errors	**2.93**	**2.79**	**3**	**2.9**	**3**	**4.72**	**3.5**	**3.25**
4. Senior managers foster a positive safety culture within our organization	**2.93**	**2.5**	**3**	**2.81**	**7**	**4.94**	**2.0**	**4.5**
14. Our management is responsive to concerns	**2.93**	**2.64**	**2.93**	**2.83**	**5.5**	**4.61**	**5.5**	**5.5**
11. My supervisor treats staff fairly	**2.93**	**2.71**	**2.93**	**2.86**	**4**	**4.44**	**8.5**	**6.25**
16. Our management demonstrates that people are valued	**3**	**2.79**	**3**	**2.93**	**1.5**	**4.39**	**11.5**	**6.5**
6. Senior managers put ensuring protection of people and environment above all other priorities	**2.86**	**2.5**	**2.86**	**2.74**	**10**	**4.72**	**3.5**	**6.75**
15. Our management encourages open discussion	**2.86**	**2.57**	**2.86**	**2.76**	**8.5**	**4.61**	**5.5**	**7**
3. Senior managers motivate employees	2.93	2.57	2.79	2.76	8.5	4.44	8.5	8.5
10. My supervisor helps me when I encounter a problem	2.79	2.86	2.86	2.83	5.5	4.17	16	10.75
7. Senior managers ensure strategic goals are aligned to the regulatory mission	2.86	2.57	2.57	2.67	13	4.41	10	11.5
5. Senior managers support employees to fulfil their responsibilities	2.93	2.43	2.71	2.69	12	4.39	11.5	11.75
2. Senior managers consistently ensure effective regulation	2.71	2.14	2.43	2.43	17	4.5	7.0	12
12. My supervisor seeks my input	2.71	2.71	2.71	2.71	11	4.22	14	12.5
8. Senior managers ensure that our safety culture programme is clearly identified and integrated into our strategy plan	2.71	2.29	2.64	2.55	15.5	4.29	13	14.25
9. Senior managers consider the relationship between individuals, technology and the organization	2.71	2.07	2.86	2.55	15.5	4.18	15	15.25
17. Leadership skills are systematically developed	2.79	2.43	2.64	2.62	14	3.94	17	15.5

As well, experts identified the need for more research on this concept and development of tools for assessment. Study 2 attempted to address this need by evaluating the 144 regulator safety culture items developed by a working group on safety culture. The results of this evaluation were used to identify the 71 most positively rated items.

Limitations existed in the present studies. For example, the sample used in Study 1. Participants were subject matter experts in safety culture but not all participants had experience in a regulatory environment. Thus, findings may have presented differently if participants had extensive regulatory experience in addition to safety culture expertise. In the second study, both SMEs and regulator employees were very positive in their assessment of the survey items, which made it difficult to reduce the number of questionnaire items. It is therefore possible that good items will not be included in the next phase of questionnaire evaluation.

The need for regulatory bodies to better understand their influence on operator safety culture is highlighted by findings from accident investigations. Understanding this influence as a manifestation of regulator safety culture has recently been presented, prompting new direction for this research [2]. Moreover, to date, no scales have been published measuring this construct. The current study produced a framework representing regulator safety culture and evaluated an initial draft of a regulator safety culture perception scale. More research is needed to further refine the scale and future research should assess its factor structure and the relationship between the scale's dimensions and relevant organizational and safety variables.

It is hoped that the findings from this study provide a first step in facilitating assessment of regulator safety culture in order to advance a regulator's ability to oversee industry safety and prompt additional research on representative frameworks and assessment methods.

Appendix A: Themes and Example Statements

Theme	Examples of Participant Statements
Leadership commitment to creating a positive safety culture	"good management is the key to everything […] good management is key to having a good culture […] good management in terms of making sure that people are not overworked and not put under enormous amounts of pressure for the kind of things they have to do… That they have deadlines that are actually manageable, that their managers make decisions and help out." "a strong safety culture is one in which the leaders demonstrate that safety is their overriding value and priority. […] the leaders must be talking about it and be seen to, with sincerity, believe in safety."
Proactive, risk informed and flexible approach	"…going back to Three-mile Island as an example, when the [regulator] got involved too much into the hands-on event response in the control room, this is an

(*continued*)

(*continued*)

Theme	Examples of Participant Statements
	example of a regulator's direct safety culture impact on the licensee. So it's up to the licensee to figure his own solutions they're the expert to run or save the plant. The regulator shouldn't be in the control room to pull levers." "…the primary is the understanding of the nature of risk of the industry that they are regulating." "on the one hand there is the mutual respect and partnership philosophy and on the other hand there's the policeman philosophy." "…I think that good regulators […] spend as much time doing off the record stuff as they do on the record stuff." "a good regulator will also be able to, you'll be able to meet the person over a cup of coffee, have a discussion without any notes being taken, papers shown, in order to reach a clear understanding."
Continuous learning and self-improvement	"I think competence of employees, both theoretical and practical is key to how well the regulator works." "so you've got cognitive competence, which is the knowledge. You've got the functional competence which is the skill set or the ability enact the knowledge in physical terms… but then you've got the wider organizational culture that has you set up to be able to give you the means to display that, and to keep up to date. So educational opportunities, systems that support what you're asking people to do."
Unwavering ethical standards	"how to think of the national nuclear infrastructure and how things [such as political pressure] are influencing each other in ways, in intended ways but very often in unintended ways and dynamic ways that is hard to foresee […] and that is also difficult to formalize to have lots of people thinking of that and talking to each other." "how does the regulator react to the public and under political pressure and how independent is it?" "too cozy a relationship between the regulator and the regulated [can lead to questionable practice]".
Transparency through communication	"…the regulator now that some intolerance of let's say risks or perceived risks, this is rapidly become an exercise of PR and it shifts the message into everything you say: everything is safe, without having the capacity to say yes, it is safe, they've been operating safely however, they need to fix A, B, C and D because they are having issues and struggles here and there. We are at that place now where we are caught between a rock

(*continued*)

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Theme	Examples of Participant Statements
	and the hard place and that is becoming a systemic issue and it's a capacity to report issues of performance in transparent manner without jumping the guns to the necessity of closing the plant."

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Role of Emotions in Risk Perception

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Abstract. Emotions play an important role in risk perception. There are many ways in which users' personal feelings can impact their evaluation of and reaction to product risks. Strong emotions and overall affect can influence behavior and decision-making in a manner distinct from related stimuli. In order to explore this relationship, the process of risk-benefit analysis is observed through an evaluation of several different activities and products, such as adrenaline sports, gambling, and smoking.

Keywords: Adolescent · Emotion · Perception · Self-esteem · Affect · Fear appeal · Adrenaline

1 Introduction

Product users' emotions impact their evaluation of and reaction to risk; five facets of this relationship are explored. Several strong emotional responses are isolated and discussed regarding their overall effects on comportment and decision-making processes. Affect, an overall psychological state of feeling 'positive' or 'negative' is explored in terms of the impacts and limitations of this construct. An assessment is presented concerning the impact of risk and benefit perceptions through the lens of select activities and products. Finally, adolescents are evaluated as a distinct group, with an emphasis on how their development influences risk perception and behavior.

2 Anger, Fear, and Anxiety

The experience of fear is a useful tool in order to avoid potential dangers while navigating through life. Thus, the inability to sense fear becomes a disadvantage because perceived threats cannot accurately be assessed. The neurological basis of emotion resides in the amygdala, which is a structure located in the limbic system. The amygdala plays a key role in encoding emotional memories and is responsible for modulating emotional memory storage throughout the cortex [1].

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Studies on rats have shown that animals with lesioned amygdalae display no fear response in addition to flat affect; notably, these rats did not display a fight or flight response to dangerous stimuli, including snakes. Case studies in humans, most famously patient S.M. [2], provide information on this phenomenon; S.M. did not show any fear response due to a damaged amygdala. When researchers exposed her to stimuli that would ordinarily cause a fear reaction (snakes, rats, and a haunted house tour), patient S.M. showed no sign of fear even though she exhibited other emotions. This suggests that the amygdala plays a pivotal role in eliciting fear responses in both animals and humans.

The Drive Reduction Theory [3] plays a key role in understanding when and why fear-based appeals work. This theory suggests that any state of unpleasant being, such as hunger, thirst, and fatigue, needs to be returned to baseline, thus motivating individuals to act in a way that counters accordingly. Fear is categorized as an unpleasant state, and based on this theory humans will find a way to decrease negative feelings resulting from fear by cognitively searching for a response that mitigates the circumstance. This theory helps to decode the complicated relationship between risk and fear appeal.

Although at face value, fear appeals appear to be an effective persuasion method or marketing tactic, this strategy only produces desired outcomes when combined with planning. A study whose findings support this claim [4] utilized pamphlets to modulate both fear appeal and level of planning. The findings indicated that difference in fear level had an impact on attitude but not on action. Those who were exposed to high fear messages in addition to the planning aspect in turn had higher rates of action. It is important to note that the action plan alone did not have an effect on action or intent; therefore, both high-fear appeal and an action strategy are necessary to facilitate a change in behavior.

Anger, fear, and anxiety are powerful motivators for action and behavior. One behavior that many people try to extinguish is smoking cigarettes. Combining a common fear, such as mortality or declining future health, with graphic images depicting lung cancer and other negative impacts of smoking, can have an effect on the behavior of the smoking population and its intentions to quit.

The consequences of smoking have been widely understood since the Surgeon General [5] released information on smoking and its impact on health. Smoking not only affects individual smokers, but also the health of their families and bystanders; the effects of second-hand smoking are well documented. Anti-tobacco organizations have campaigned to have cigarettes banned from public areas and have tried to curb smoking as an addiction. Many studies have conducted text-based fear appeals, but not on the use of a graphic fear approach.

Graphic fear appeal is the placement of detailed health-related consequences of smoking on cigarette packs. Researchers [6] have postulated that employing a graphic fear appeal will increase sensitization as a result of individual smokers constantly re-evaluating future risk associated with smoking. Results show that fear-based appeal methods work on certain subgroups of smokers. Individual differences, such as number of cigarettes smoked per day and disengagement level, explain variance in responses to a repeated graphic fear appeal. The number of cigarettes an individual smokes per day influences the effect of a fear-based appeal because low-count smokers perceive a lowered risk of smoking consequences compared to high-count smokers. Disengagement level refers to the act of countering cognitive dissonance with phrases such as "I have old relatives who smoked and lived a long life." This type of thinking lessens the effect of a fear-based appeal because it allows for an exception, which in turn is used as a defense by smokers [6].

Graphic fear-based appeals have high efficacy for subgroups that consist of heavy smokers and are low in disengagement. Because heavy smokers typically rank higher in perceived risk of smoking and health consequences, graphic fear appeals contribute to the level of risk perceived, and therefore have high efficacy for increasing intention to quit smoking. On the other hand, the subgroup that ranks low in disengagement is more susceptible to these appeals regarding smoking behavior [6] because their impression of smoking is not negated by exceptions that would permit them to continue to smoke without encountering cognitive dissonance. Although it is a difficult task, it is possible to persuade certain subgroups of smokers to quit, or at the very least garner intentions to quit. Thus, the efficacy of graphic appeals on cigarette labels indicates how emotions play a pivotal role in risk taking and product risk perception.

3 Risk Perception and Affect

Affect is the culmination of subtle feelings experienced on a daily basis, resulting in an overall positive or negative state of being. The affect heuristic suggests that overall positive feelings result in a perception of lowered risks and raised benefits while negative feelings are found to have the opposite effect. The limitations of these observations are described through an exploration of cognitive processes, in which emotions share an affect that results in risk and/or benefit perceptions.

3.1 The Affect Heuristic and Valence Theory

In analyzing risk perception, it is imperative to discuss the impact of the affect heuristic and valence effect. The affect heuristic states that when confronted with a decision, an individual will use the immediate and subjective feeling of general positivity or negativity about the situation to assess risk. A feeling of positivity signals low risk, while a feeling of negativity signals high risk. As with all heuristics, the affect heuristic is an automatic shortcut that aids individuals in making quick decisions while also serving to minimize cognitive energy expenditure [7]. The valence effect, on the other hand, is a concept that suggests that the general population tends to expect and overestimate the probability of positive outcomes, which plays a role in distorting the perception of risks.

A study [7] examined the relationship between the assessment of risks and benefits that are inherent in decision-making. The data gathered show that the affect heuristic has more influence in time-pressured situations and that risk and benefit are inversely related. There was a significant increase in perceived risk for individuals under time pressure compared to those who were not, signifying that the affect heuristic functions in quick decision-making. Additionally, researchers found a causal inverse relationship between risk and benefit, such that if participants were presented with a high-risk scenario, they would judge it as low benefit, whereas if they were presented with high benefits, the participants would judge it as low risk. Following this theme, it is possible that affect is the key that links risk and benefits, which is why the affect heuristic is important in decision-making.

Although the affect heuristic is useful in making everyday decisions, it is important to note the limitations of this mental shortcut. While the affect heuristic is generally correct, when paired with the availability heuristic, described in the next section, it can lead an individual astray due to the subjective nature of these automatic judgments.

3.2 Cognitive Dimensions

While the affect heuristic is generally useful as a mental shortcut, it is not infallible. For example, the availability heuristic, which is a mental shortcut based on availability of information, may be relevant when making decisions; the more often we are exposed to a certain stimuli, the more we are able to recall it [8]. For example, the general public, when asked, will agree that earthquakes occur more frequently in California than Virginia; this is an example of the availability heuristic being accurate. However, people are also likely to say that more humans die from car accidents than heart disease, which is incorrect. Although intuitively it would seem that car accidents are more deadly than heart disease, this is in fact a false perception caused by the availability heuristic and its portrayal through the media and other avenues. More often than not, the media reports on fatalities due to car accidents as opposed to heart disease. Thus, the availability heuristic can work both in our favor and against us, when judging risk.

4 Activities and Products: Perception of Benefits vs. Risks

Risk-benefit analysis can be evaluated by discussing its impact on several different activities and products. Sensation-seeking and emotional control regarding adrenaline sports and gambling are discussed with an emphasis on addictive behaviors.

4.1 Adrenaline Sports and Gambling: Sensation Seeking and Emotional Control

Adrenaline sports and gambling are two very different activities, but share many commonalities including motivation and an individual's need to control the environment. Both adrenaline sports and gambling revolve around polarized risks and benefits [9, 10].

Although the average person may deem adrenaline sports as irrational, an arguably logical assessment of risks versus benefits still occurs. While fear may not motivate their decisions, more positive emotions such as happiness and excitement-seeking play a key role in benefit and risk perception. Although the term "adrenaline sports" is viewed as a means for sensation-seeking, different kinds of high-risk sports serve different purposes for those who engage in them [9]. To illustrate, the goal of

Fig. 1. The goal of mountaineers is to obtain agency through emotional control.

mountaineers is to obtain agency through emotional control while on the other hand skydivers meet their sensation-seeking need through participation in their sport [9]. Skydivers whose need for experiencing high adrenaline levels are satisfied after they complete their jump. The need for emotional regulation is not present because the nature of the sport is fleeting, leaving no opportunity to gain emotional discipline. On the other hand, the agency that is experienced by mountaineers serves to increase regulation of emotions (Fig. 1).

When assessing risk and reward, different motivations need to be considered. It is easy to characterize seemingly similar activities into one group, yet parsing the differences between each unique activity can shed light on the perception of risk and reward. For example, casinos have tapped into the psychological construct of providing hope of big wins, but actually supplying huge losses, and yet continue to have customers return to the slot machines. What is it that makes gambling so attractive to many people, and how is the perception of risk involved?

The addictive quality of gambling can be analyzed in relation to reinforcement strategies, coupled with environmental factors [11]. Reinforcement strategies stem from behavioral psychology, which includes shaping behavior via rewards. There are many different types of reinforcement strategies; the most applicable strategy is variable ratio schedule, when rewards are offered after a variable amount of trials, rather than after a set number of trials. This increases the level of anticipation for participants. The type of reinforcement schedule employed to shape behavior influences the extinction rate of the behavior. Continuous reinforcement has a high rate of learning, but a rapid rate of extinction; once the rewards stop, the behavior will cease quickly. The variable ratio schedule takes the longest for participants to learn, but in return, has a very slow extinction rate.

Gambling uses the variable ratio schedule of rewards, which explains its addictive qualities. The variable ratio schedule creates a belief that says, "Maybe I'll win big if I spin just one more time"— the key to gambling addictions. Coupled with the fact that extinction takes longer for this type of reinforcement schedule, gambling is an activity that both prevents people from being able to perceive immediate risk and causes them to forgo thinking about long-term risk [11].

Environmental factors also influence the desire to continue gambling. Casinos are usually dimly lit and do not have clocks, creating the illusion of timelessness. Additionally, casinos often hire attractive people, appealing to our innate perception that attractive people possess desirable qualities and characteristics; thus, the presence of reward cues, attractive people, lessens the impact of losses, and as a result leads to behavior that increases financial risk [12]. This allows patrons to continue gambling despite their likely financial decline.

5 Interpersonal Relationships

Interpersonal relationships are crucial to accessing certain feelings, such as love and belonging. With the increase in technology, the landscape for building relationships has changed, thus altering the nature in which we connect with one another and the risks associated with it.

5.1 Social Media and Dating

Social media often plays a significant role in dating in today's world. The increasing influence of the internet and social networking sites (SNS) has changed the landscape of interpersonal relationships in recent years in astonishing ways. Allowing people to communicate and to create relationships online without face-to-face contact is a significant difference from the past. Although it may seem more convenient, online dating can have negative consequences on self-esteem.

The use of SNS, such as Facebook, have been empirically shown to have a profound effect on self-esteem. Because SNS provide easy access to information about other people's lives, people can compare themselves to others. Studies show that individuals who use Facebook most frequently have lower self-esteem as a product of constant upward comparison [13]. The purpose of comparing oneself to others satisfies the innate need to belong and to exist as a contributing member of society. SNS promote impression management and allow people to control how others view them in order to gain higher social status. However, comparing oneself to more superior-seeming individuals results in upward comparison, thus lowering self-esteem.

Self-esteem is critical in maintaining relationships. Individual level of self-esteem is highly indicative of emotional regulation and behavior in situations of risk. When confronted with relationship conflict, high self-esteem (HSE) individuals tend to perceive the relationship in a more positive light compared to low self-esteem (LSE) individuals. These differing perceptions produce two different motivations for conflict regulation. HSE individuals pursue approach-directed goals, whereas LSE individuals move towards avoidance-directed goals [14]. HSE individuals tend to seek intimacy and closeness with their partner, while risking rejection. Their goals extend beyond the relationship to situational rewards and an increased level of risk in the hope of gaining a higher level of rewards. LSE individuals respond to risk by inherently protecting themselves, and pushing their partners away in fear of perceived impending rejection; this strategy is more conservative and risk-averse.

Research indicates that vulnerability between intimate individuals is imperative for a successful relationship. This can be achieved if both people believe that their feelings are being reciprocated; people do not want to risk rejection by being vulnerable to someone who does not mirror their affections. HSE individuals correctly assess that their partners see them in a generally positive light, whereas LSE individuals continuously underestimate the positivity in which their partners view them [15]. This finding suggests that LSE individuals are less satisfied in their relationships because they use themselves as a template for how they are perceived, an example of false consensus bias. LSE individuals cope with their vulnerability by creating distance and hesitate to become more intimate. They also tend to become less generous and attribute negative events to their partner's disposition, which ultimately results in less relationship satisfaction.

High use of social media decreases self-esteem as a result of upward comparison, and causes negative outcomes for those with low self-esteem. Because of the inherent risk of rejection that comes with dating and relationships, people with low self-esteem react in a way that protects them from emotional harm [14, 15]. In these cases, the risk of rejection clearly outweighs the potential gains of fulfilling the need to belong, which cripples both interpersonal and romantic relationships.

Differences in risk stimuli can affect people's response to their surroundings as well. Although it is difficult to empirically study love due to its highly subjective nature, it is possible to study arousal and how individuals assess risk in certain situations in order to better understand the underpinnings of attraction and romance.

Prior studies have suggested that fear-based arousal can be misattributed if the source of the arousal is ambiguous. A study [16] illustrated that men are more likely to perceive a woman as attractive if their sympathetic responses are heightened, as compared to resting state. Likewise, a study using roller coasters resulted in similar findings [17]; participants were more likely to rate their date as more attractive immediately following a roller coaster ride versus those who did not ride and who engaged in an activity with little to no arousal. Both of these studies suggest that arousal can be misattributed when risk is involved, especially when the source is ambiguous. This type of misattribution can occur during any activity that causes high arousal. These two studies support Schachter's theory of emotion [18], which suggests that emotion comes after cognition as a result of physical arousal.

6 Adolescents

Development and experience affect emotional control and risk perception which influence adolescent and young adult behaviors. This analysis is related to the risk-taking behavior and use of products that are considered hazardous, including alcohol, marijuana and cigarettes, and the emotional component behind their use as well as propensity for abuse. An adolescents' self-esteem can contribute to illicit substance abuse.

6.1 Difference in Emotional Control and Risk Perception

Emotional control, or lack thereof, is a strong predictor of risk perception. Impulsivity, a measure of lack of emotional control, is a prevalent characteristic of adolescence. A study [19] investigated the difference between sensation-seeking and impulsivity in relation to age, evaluating whether they influence each other. Sensation seeking shows a curvilinear pattern, peaking between the ages of 12–15. In contrast, impulsivity steadily decreases in a linear fashion as an individual matures, especially between ages 10–30. Adults generally do not engage in risky behavior as frequently as adolescents do, which prompts us to believe that there is a correlation between level of emotional control and risk perception [20]. Overall, it is important to note the differences in impulsivity and sensation-seeking to better understand how risk is assessed, so that we may better address serious behavioral issues such as driving under the influence, under-age smoking, drug abuse, and unprotected sex.

6.2 Alcohol and Controlled Substance Use

Adolescents are prone to many environmental risks, especially increased opportunities to consume alcohol, cigarettes, and controlled substances. Decreased emotional regulation and the resulting poor ability to perceive risk, is a characteristic of adolescents, and plays a part in that cohort engaging in these hazardous activities [21].

In most U.S. states, individuals must be 18 or older to buy cigarettes. Of course, this does not bar adolescents younger than 18 from gaining access. Although many adolescents experiment with cigarettes, fewer than would be expected progress to heavy smoking [21]. This evidence, however, does not suggest that adolescent smoking is not a pervasive problem. Gaining insight into how and why smoking becomes a habit is imperative for the health of future generations.

Research in this field [21] has examined affect regulation as a cause for smoking. Affect regulation is the ability to respond accordingly to affective changes, a skill learned and refined during adolescence. Evidence from recent studies suggests that affect regulation and mood variability are related concepts, and that both are linked to smoking outcomes of experimenting adolescents.

The ability to regulate affect has an impact on mood variability. A higher level of affect regulation results in normal mood variability and is an intrinsic mechanism of control. Adolescents who are unable to control their affective processes do not have the necessary intrinsic faculties to stabilize their emotions and instead need an extrinsic factor to regulate mood. Continuing this line of reasoning, adolescents who have negative mood variability as a result of insufficient affect regulation are the most prone to making smoking a daily habit [21]. These adolescents use smoking as a form of regulation rather than relying on internal regulatory processes.

Within the lens of risk perception, it would seem that adolescents who regulate mood variability via smoking do not perceive an increased risk associated with continued smoking due to their improvement in overall affect control. If the purpose of smoking a cigarette relieves current negative mood tension, then the perceived risk of future health problems and consequences is not as pertinent, especially to an adolescent who has difficulties managing affect [21]. The process of turning experimental smoking into a habit is a result of affective change. Adolescents who have negative mood variability are more likely to start smoking initially, but what determines if it becomes an ongoing habit is mood variability improvement. If mood variability normalizes over the course of time, then this improvement reinforces this positive change and therefore pushes the adolescent past the experimentation point into habit.

Another pressure that adolescents face is exposure to alcohol and the risk of subsequent abuse. Adolescent alcohol use is a serious concern because it has both short-term and long-term health risks and is prevalent in teenagers in many parts of the world [22]. One factor that predicts alcohol abuse is the attachment style of the adolescent to three primary groups in their lives: parents, school, and alcohol-using peers. This type of analysis relies heavily on social learning theories and the influence of external interactions as the cause of alcohol use in adolescents. From the beginning, children learn about the world through imitation and observational learning. As they enter their teenage years, the role of the parent decreases, and the primary influence in an adolescents' life is the peer group. The pressure to conform is powerful for many adolescents, especially where alcohol exposure is prevalent.

High attachment to parents and school predicts little to no alcohol use in adolescents, because the adolescents' need to conform to expectations of these prosocial groups curbs their interest in experimenting with alcohol. Additionally, individuals who identify strongly with both parents and school perceive a high level of risk associated with alcohol because there is no disengagement present [22]. As discussed, disengaging thoughts are ones that provide an exception to an otherwise negative activity, which lessens cognitive dissonance and thus increases the chances of engaging in negative behaviors. On the other hand, adolescents who identify highly with antisocial groups, or peers that abuse alcohol, are more likely to abuse alcohol because they do not feel pressured to conform to conventional norms, such as avoiding alcohol as a minor. Their perception of risk is decreased because the presence of disengaging beliefs is high, which in turn allows them to have an excuse for drinking alcohol, even though it is counter to societal rules.

Substance abuse is linked to an individual's level of emotional regulation. One interesting characteristic that predicts substance abuse is whether or not an adolescent is monoracial or multiracial [23]. Within recent decades, there has been an increasing number of multiracial children. These children not only have to deal with the emotional changes that come with adolescence, but also have to tackle the inability to belong to a single racial group; they may juggle multiple identities while not identifying with any one cultural group, which can result in social isolation and increased feelings of insecurity.

Low self-esteem often breeds insecurity, which entails poor emotional regulation and other psychological health symptoms. A study [23] found supporting evidence that corroborates this phenomenon while also linking insecurity to increased levels of substance use. Multiracial and monoracial adolescents, including minorities, were both tested. Multiracial adolescents performed significantly more negative behaviors such as substance abuse and violence. Even when compared to monoracial members of minority groups, multiracial adolescents showed this higher correlation. Multiracial adolescents constantly have to cope with two racial identities while trying to conform to norms in order to feel accepted. The struggle with the inability to identify with a single race has many psychological outcomes that contribute to higher levels of substance abuse, and low self-esteem.

It is clear that emotional dysregulation and lack of perceived risk play a key role in adolescents gravitating towards making cigarettes, alcohol, and illicit substance use a habit. In order to curb these behaviors, it is imperative to target each individual's ability to regulate emotions rather than just treating symptoms.

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Safety Culture in the Ergonomics Perspective: Case Study in Offshore Platforms

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Abstract. This paper aims mainly to present the methodology and the main results of the diagnosis on safety culture (or human and organizational factors) carried out in two offshore production platforms in Brazil. The main methodological stages were: (i) application of a questionnaire on safety culture and (ii) group discussion of the divergences of perception among the different hierarchical levels. The integration among the platforms' operating teams and the company's engineering areas may be pointed as the main condition for the development of the proactive and generative safety culture.

Keywords: Safety culture · Ergonomics · Offshore platforms

1 Introduction

Since its emergence shortly after the Chernobyl accident in 1986, the concept of "safety culture" has been at the center of concerns of various organizations, professional and academic communities in the "Safety Sciences" field. It emerged as an alternative to the safety approaches used in high risk companies and organizations. Such approaches traditionally in use are criticized, above all, due to the limits related to the integration of the human dimension in its safety practices or, in other words, to the limits related to the understanding of the specificity of human nature, its needs and its contribution to industrial safety.

The approach of Safety Culture or Human and Organizational Factors of Safety (FHOS) used in this project consisted in identifying and implementing conditions which favor the positive contribution of the operators and the collectives of work to the construction of industrial safety. Industrial safety is considered as one that integrates:

- standardized safety – which takes into account anticipations through rules and procedures – and
- safety in action – which takes into account the workers' actions (often absent from the rules) in favor of safety.

To build or to develop a safety culture is to consider the human dimension in organizations, inviting them to mobilize levers and motivations for action other than exclusively the compliance to norms.

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2 Integrated Industrial Safety

The knowledge proposed by the approach of human and organizational factors of industrial safety [1] and by the ergonomics of activity [2] allow not only a better understanding of what affects human activity, but also to act on the conception of work situations aiming at the development of a safe activity. Thus, for the development of safe production units, action on the individuals' behavior (in terms, for example, of compliance with rules) is not enough. It is necessary to act, above all, on the project and transformation of the characteristics of the work situations.

The main way to noticeably reduce the likelihood of emergence of undesirable behaviors for safety is to act on the situation characteristics, which includes local characteristics such as the process project, the work place, the tools, and more global characteristics such as the company's purchase policies, labor training plans, recognition and sanction policies, among others.

Efforts made in this direction may result not only in improvement in safety results, but also in quality of production or safety at work (accident frequency rates).

Human behavior is the visible part of something broader: the human activity. Besides postures, movements, verbal and nonverbal expressions or the use of a tool, the activity contemplates the body mobilization for this behavior. In other words, behavior is the visible dimension of the activity, which also includes perceptions, reasoning, memory, knowledge, decision making, emotions and so on.

Thus, the work activity is a response to different situation determinants such as the production objectives, the tasks to be performed, safety rules, people's skills, the means available and the conditions of work performance provided by the company. The activity is never the simple performance of a procedure. It is the result of a regulation process among the different determinants mentioned above.

Recent studies on industrial safety [1] classify human behaviors into two main categories: human behaviors in compliance with the rule and initiative behaviors.

The behaviors of compliance to the safety rules would be, for example: the use of IPE, respect for critical procedures such as work permits and inspections, order maintenance, cleaning and organization of workspaces, the use of the handrail when going up and down stairs, and so on. The degree of compliance varies according to the rules, among groups and companies as it is impossible to prescribe motivation, trust and cooperation.

Initiative behaviors in safety are the second category. In two situations, they are emphatically mentioned: (i) in situations where there are conflicts between procedures or existing norms and (ii) situations to which there are no prescriptions. In these two cases, decisions that involve the safety of the premises are the responsibility of those who face events often unforeseen and unknown. Examples of initiative behavior are:

- To signal risk situations
- To propose modifications in equipment or work environment
- Various participations in safety improvement activities
- Recovery from real risk situations
- Shared surveillance
- Creation and dissemination of safe practices.

3 Safety Culture

The definitions of safety culture are many. It may be defined as a set of beliefs, values and behaviors shared by the different actors of an organization [1]. For the OGP (International Association of Oil & Gas Producers), safety culture is defined in a similar way: it is about attitudes, values and beliefs that support the way things are done in an organization ("the way we do things here").
The OGP highlights that:

- A positive safety culture is mostly supported by trust, credibility and the behavior of their more senior leaders. Trust is considered extremely fragile and, when lost, it is extremely difficult to recover;
- The search and maintenance of a positive culture in Safety Management System - SMS is not a discrete event, but a long path. Organizations should never lower their guard. The companies should make sure that their senior management is always committed to this long path;
- The development of methods and tools varies according to the level of organizational maturity: a tool will not produce the desired improvement if the organization is not ready for it;
- Thus, the use of certain tools may not be effective, and may even be counterproductive according to an organization's culture level.

For [3], the main elements of a safety culture are:

- Information: safety culture is information culture, in which data need to be collected, analyzed and discussed in the organizations;
- Report: people have confidence in being able to report safety problems without generating culprits or punishments;
- Learning: the organization learns from its mistakes and transforms unsafe conditions;
- Flexibility: the organization is able to reconfigure its hierarchical chain according to events and context;
- Coherence: a culture seen as coherent and fair in relation to acceptable and non acceptable behaviors, and also trustworthy in effective preventive measures.

For this author, safety culture may be built or "engineered" having as basis the factors mentioned above.

Based on researches on the practice and safety management tools used in the oil and gas industry, the OGP has developed a safety culture classification for the organizations and production units, which was used in this work. The main categories of safety culture for the OGP are presented below:

- Pathological: causes of accidents are solely associated to individuals, especially those of the lower hierarchical levels; the managers only implement what is mandatory (including evaluations and audits); the tools do not work well at this level;
- Reactive: most of the problems are linked to the workforce in the lower hierarchical levels; simple SMS tools acting only in behavioral issues (unsafe behaviors and

campaigns); in practice, production comes before safety until an accident occurs; tools that deal with issues that have not yet caused accidents are difficult to operate;
- Calculative: the use of a large number of tools and trainings; the analyzes refer to the quantitative logics; the tools are often contradictory and may be associated to risk situations; the tools are almost exclusively top-down; SMS professionals are seen as the only responsible people for the creation and the use of rules, tools and SMS performance;
- Proactive: the leaders understand that failures in the management system are the primary causes for incidents; risk situations and real incidents are daily used to generate learning situations among the workers; tools that simplify the work are used; leaders of all hierarchical levels assert the right of refusal;
- Generative: the SMS tools cover all hierarchical levels; mandatory tools do not exist as they are counterproductive and generate mistrust among the operators; everyone feels at ease to evidence actual and potential problems; the leaders provide the necessary support for the problems raised; the workers have power to act in order to deal with field situations.

4 Methodology

The main phases of the methodological approach used were:

1. Preparation of the questionnaire on the perception of rig safety (including definition of shipments);
2. Application of the questionnaire in different groups: (i) the company's operators and maintenance technicians, (ii) managers and coordinators, (iii) hired maintenance technicians, (iv) cargo handling team, (v) hotel team and (vi) supervisors of the hired teams;
3. Analysis of the answers through Sphinx software;
4. Implementation of discussion groups;
5. Synthesis/Restitutions (meetings of presentations of the research results).

The steps above can be summarized in a quantitative phase (steps from 1 to 3) and in a qualitative phase (steps 4 and 5), which was based particularly on meetings with the different groups. The diagnosis quantitative phase had the following main characteristics:

- Assessment of the perception of safety at all company levels by means of a 60-question questionnaire built from the literature.
- Expressive participation of managers, operators, technicians and workers of the two rigs (85% of the population of one of the rigs and 77.5% of the other answered the questionnaire) and different safety aspects were covered.
- Manual individual filling out in collective sessions per group. Two or 3 sessions were performed for each group.
- Anonymous: the respondent was not identified when filling out the questionnaire.

As mentioned before, the 60-question questionnaire was divided into 5 large themes:

- Reliability of the rules, mistakes and deviations: the goal was (i) to understand whether the workers and managers believed the rules to be absolutely reliable or if there might be situations in which the rules are not enough and (ii) to understand if there are mistakes and violations of the safety rules and why;
- Accidents: the goal was to understand the respondents' perception about the origins of accidents, whether the culprits are sought, if there are prevention methods based on the declaration of field anomalies and what the leaders' corrective measures are to prevent new accidents;
- Debate on anomalies and reminder of rules: a set of questions sought to understand the respondents' perception about the efficiency of the spaces for discussion about safety, such as weekly and daily meetings;
- Safety discourse and practice: the goal was to understand whether the leaders' practice in terms of safety match their discourse;
- Safety sensation on the rig: part of the questions was dedicated to demonstrate whether the workers really feel safe in the different work situations they face on the rigs studied.

The diagnosis qualitative phase was mainly characterized by a set of collective interviews that mobilized the different groups that answered the questionnaire. A debate on the convergences and divergences of the answers was carried out with each group separately. The goals were:

- To complement the quantitative diagnosis;
- To clarify the interpretation of certain results of the questionnaire;
- To recover concrete examples of work situations related to safety;
- To define the main classes of safety problems faced by the work teams according to the workers' perception;
- To capitalize the ideas of improvement in terms of safety and accident reduction.

5 Main Results

As mentioned above, the answers to the questionnaire were treated by the Sphinx software. This tool allows us to observe the absolute numbers generated by each answer, in addition to generating graphs, statistics and a general note about each one. This general note allows for the evaluation of whether there is convergence or divergence between the answers of the different groups. It may be verified, for example, that there was convergence between the different groups in relation to:

- Cause of accidents: most of respondents in the different groups believe that accidents are not fatalities or fortuity;
- Availability of Individual Protection Equipment. They all agree that IPE is made available by the company;
- Management's incentive to interrupt the work if potential risk is verified by the operator;
- Maintenance of order and cleanness is regarded as priority and is always required by the leaders on board

While there are convergences between the perceptions of the different groups interviewed, other results point to divergences in other aspects. The divergences verified in the answers were classified into 9 different types according to the nature of each divergence, and they were named as follows:

1. Safety discourse and practice
2. The process of creation of rules and bureaucratization of the system
3. Inconsistency of the rules
4. Safety or Production
5. Blame for the accidents
6. Register and treatment of anomalies
7. Meetings about safety and reminder of rules
8. Safety of the hired workers
9. Safety of the numbers

Based on the answers to the questionnaire, and mainly on the discussion groups, we can claim that the safety culture of the rigs studied may be classified, according to the OGP (International Association of Oil & Gas Producers), as managerial, although elements of the pathologic culture (for example, in relation to the perception of the search for culprits) and the reactive culture (which can be identified by reactive campaigns towards unsafe behaviors common in the company) can be found.

6 Discussion

The concept of "safety culture" comes from the awareness that, in spite of all its contributions, technology is not the only source neither the only solution for the problems and challenges of industrial safety. This concept was conceived to reintegrate the human dimension, its competences and symbolic productions (beliefs, values, cognitive capacities, etc.) in the construction of safe production systems. Aiming to control the risks related to the operation of complex social-technical systems, safety culture is considered as a promising alternative in the field of industrial safety [4].

The emergence of the notion of safety culture has made it possible to sensitize the organizations to the challenges of the representations and the value of human work for industrial safety. It has also made possible to understand how and why the effective involvement of the individuals in their activities occurs. In a wider sense, it may allow for the integration of what is experienced in the organizations' daily activity with the safety practices. This renewed approach to safety is even more necessary and pertinent when the organizations have to face unprecedented challenges, born from the complexity of the economic, technical and organizational environment in which they operate. In this extremely complex environment, strictly technical and managerial approaches have not favored improvements and present limits already verified in practice.

In these thirty years after the emergence of this concept, one may say that consensus has not yet been achieved concerning a definition and a typical approach for the construction of a safety culture [5]. The main criticism towards this approach reveals that its putting into practice only through tools and safety management methods has emptied the focus on its essence and specific attributes, thus diverging from its original project, i.e., the development of the human dimension in safety matters [6]. The question that arises now is how to rescue this path and build an approach that may consider the human dimension in its specificity and not as just a factor like many others.

To build and develop a safety culture is to consider the human dimension in the organizations, inviting them to mobilize levers and motivations for action other than exclusively the compliance to norms. In this sense, the managers' decisive contribution for safety and, more specifically, to safety culture in industrial installations has already been well established in the Safety Sciences field [7].

Likewise, the contribution of the frontline (their own operators and maintenance technicians as well as those outsourced) is also emphasized in the Safety Sciences field [7]. It is closely related to the practical knowledge developed in the productive units' daily activity. As complete and well built as the rules may be, they do not apply to all the situations, either because they contradict one another in some cases (when arbitration becomes necessary between production and safety, time and safety, maintenance and production), or because they do not contemplate all the problems, unforeseen events and randomness typical of complex production processes. The frontline performs a daily exercise of deliberations and decisions based on the practical knowledge [1].

The choice for the OGP classification for support to this research project is due to two main reasons. It is a classification widely used and validated by the main world oil and gas producers and, in addition, it makes it possible to think of actions to promote the transformation and to move towards a proactive and disseminating safety culture. According to the OGP, the evolution and transformation of a culture is not a discreet event, it is a path to be trodden.

But what does changing a culture or developing a safety culture mean? The role of proximity managers or of those of upper hierarchical levels and their involvement are decisive here, as already mentioned. But the construction of a safety culture is not only determined by rules and procedures from the company's directors. It is established above all by the experience shared by repetitive and convergent practices [1]. According to the aforementioned author: "*safety culture is translated by the awareness shared that each one has only a part of the information and skills necessary for safety*". The practices and the spaces for discussion for feedback are more than necessary, they are a condition for this transformation. Likewise, the development of the individuals' and the different teams' initiative behaviors and power of action, in permanent discussion and dialogue with the process engineers and process safety engineers, supervisors and managers is something to be pursued in this transformation.

Thus, the actions proposed and discussed with the managers and workers for the development and evolution of a safety culture at the rigs studied may be summarized in three main points:

1. **Conception and project of the work situation:** the need to implement a transformation process of the work situations to promote operational integration between the rigs and the areas of process engineering and process safety engineering. Transformations and changes at the production units are usually necessary due to

problems unforeseen at the project stage. It is necessary that the "monologue" of the rig operation is transformed into a "dialogue" with the onshore engineering for the implementation of improvements and the transformation of perceptions.

2. **Creation of spaces for discussion for the involvement of the work force with the daily problems.** This is not about creating new meetings, but about transforming the existing ones. Thus, the DDS – Daily Dialogue about Safety, the daily maintenance meetings and others shall start to deal with problems related to the ongoing activities on the rig.
3. **Restructuration of the system of declaration of anomalies** (the current system is discredited for the report of deviations and field problems), aiming at:
   - Improvement of the alert process
   - Implementation of processes of collective discussions of anomalies
   - Feedback about the treatment performed.

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Importance of Safety Guidelines on South African Construction Sites

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Abstract. The concern for human lives on construction sites is a major issue not only for construction stakeholders but also for relevant agencies and bodies responsible for general health and safety of people in a particular society. In this study, the level of importance of various construction safety guidelines were examined with a view to creating better awareness for improved performance of construction projects. The analysis of the data revealed a minimum mean item score (MIS) of 4.13 out of the possible 5.00 for analysed safety related variables. This implies that there is a high level of awareness of various safety guidelines while the problem of implementation and enforcement of the guidelines persist. There is therefore the need for consistent and continuous training on practical implementation of the guidelines and programs by relevant construction training agencies such as Construction Education Training Agency (CETA).

Keywords: Accident · Education · Health and safety · Injuries · Training

1 Introduction

The developing nature of countries like South Africa usually lead to continuous need for construction products, which implies that the construction industry must be rightly placed to meet growing demand of the public to sustain the economy. As a result, there are several issues of concern including safety related ones, which is the focus of this study. Achieving complete safety performance in construction projects is a difficult task to achieve due to increasing number of occupational injuries and accidents on construction sites. Ensuring workplace safety is one of the daunting tasks in construction [1]. It was further noted that there is a high rate of accidents architecture, engineering and construction projects, and this portrays a bad image of the construction industry. Yates and Lockley [2] concluded that construction accidents usually occur due to construction failures, and may result in injuries, illnesses or fatalities to people and projects at large. Accidents cannot be eradicated but can be minimized. However, professionals, workers and other stakeholders in the construction industry tend to ignore various health and safety regulations and this impact badly on the construction industry, as lives are lost due to fatal injuries. Since the Health and Safety at Work Act 1974 was introduced, the rate of fatal and major injuries bas been on a decrease [3]. The Act require that appropriate strict measures and policies to control safety be in place for safety of people in all sectors of the economy, including the construction industry.

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Accidents and injuries in construction occur due to lack of attention given to safety performance and safety procedures.

Lack of knowledge and training, lack of implementation of rules as well as inadequate supervision are major causes of accidents on construction sites. Safety management is key to mitigation of unforeseen accidents on construction sites, and management behavior is drawing academic attention because it tends to be the root cause of occupational safety accidents [4]. To ensure safety of lives and properties, various safety management practices have been identified to improve organizational performances. Safety management practices helps in mitigating accidents rates, improving safety practices, enhancing productivity as well as increasing profitability of construction companies. Health and Safety Executives [5] noted that up to 80–90% of accidents at workplaces are because of unsafe behaviors. The issue of construction safety is of utmost importance and lately, the Construction, Design and Management (CDM) Regulations of 2015 have reinforced the importance of safety management in construction industry in a self-regulatory context [6].

The effectiveness and importance of adopting the ISO-system by organizations to improve their safety measures, especially in the area of environmental policies cannot be overemphasized [7]. Dodge [8] added that the importance of mandating construction workers to be certified health and safety officers is necessary in creating awareness of occupational safety, which can be helpful in successful delivery of construction projects. In view of the linkage between health and safety and performance, this study examines the importance of various safety guidelines with a view to improving health and safety of construction projects during preconstruction, construction and post-construction phases.

2 Safety Guidelines in the Construction Industry

Safety management is a way of managing risks in an incorporated manner in order to reduce accidents rates and improve company's productivity, thereby enhancing the economic and financial performance of the organizations. Safety management is a process by which several plans are put together to contain and prevent serious accidents or damage in an organizational setup [9]. Furthermore, the concept of safety management system are a set of policies, strategies, practices, procedures, roles and functions associated with safety [10]. This implies that safety management systems are tools that are designed and incorporated within an organization, and the essence is to control various hazards that can affect the health and safety of workers.

Safety management embodies regulations, policies, standards and proactive measures combined to reduce the risk of day-to-day activities. These policies and standards are designed either by organization or by industry policy makers to that to promote safety awareness as well as checkmate operational risk. As such, proactive measures are put into practice in line with the policies which varies in industries and organization based on the types of operations as well as their objectives [11].

Safety at work should be the concern of all construction stakeholders including clients, professionals, contractors and site workers. Construction workers especially should make it their duty and priority to work safely, they should avoid falling of objects and persons by following safety measures and regulations put in place on construction sites.

There are basic steps put in place to evade risks related to work at height. These steps were prepared for work at height with the aim of regulating such works [12]. The steps on how to avoid risks related to working at heights include such statements that every employer must take into account risk assessment under the regulation of management regulations after they have identified the measures that are required by this regulation. The employer must ensure that employees abide by the regulations at all time during every stages of construction, and that the employer must make sure that construction work is never carried out at heights where it is realistically applicable to safely do the work than at heights. In places where work is carried out at height, employer must take appropriate, adequate, realistic and applicable procedures to prevent injuries and hazard.

It is very vital to contemplate how falls can be prevented to avoid accidents caused by falling from heights [13]. The Commission for Occupational Safety and Health [14] of the Government of Western Australia outlined five steps to prevent the risks of falling from heights. These include control of the risk of internal falls by fully hitting, control of the risk of external falls by consecutive erection, control of the risk of falls by using advanced guard railing systems, control of the risk of climbing falls with safe admission systems as well as introduction of fall arrest and travel restriction systems. It is also necessary for construction industries, especially in the developing countries, to implement similar measures to control the risks of fall from heights.

Fall restraint and fall arrest are absolutely two non-identical procedures to stop fall from heights on construction sites [13]. The fall restraint does not allow the construction workers to fall completely by implementing strict restraints and the fall arrest involves the use of multiple and approved safety equipment components. The mainly used components are body harnesses, lanyards, deceleration devices, droplines, horizontal lifelines, vertical lifelines and anchorages. Using mobile elevated work platforms (MEWPs) is the one of the effective ways to enforce fall restraint [12]. Examples of MEWPs include such things as, pickers, vehicle-mounted booms and scissor lifts. Some of the advantages of using these work platforms are that it provide safe means for workers to work at height, construction workers can easily access work areas, toe boards and guardrails can help prevent fall from heights; and work platforms can be adopted for outdoors and indoors purpose.

The Construction Regulation of the Republic of South Africa outlined the important health and safety specifications expected of clients and designers of construction projects [15]. To ensure compliance with provision of the Act, the client shall prepare a documented Health and Safety (H&S) specification for the construction works; he or she shall provide any principal contractor who is making a bid to perform the construction work for the clients with the same documented specifications. The client shall make sure that the principal contractors (PCs) have made provision for the Health and Safety (H&S) costs in their tenders, however, the principal contractor and the agent must be provided with information that might affect the health and safety of any construction worker on site. The client shall nominate every principal contractor in the form of writing for the projects on construction sites - the designers or the principal agent may be the origin of the required information.

The client must stop any work that is not going according to the recommended health and safety plan. This can be achieved by stopping any contractor from executing construction work that do not comply with the principal contractor's health and safety plan for the site, or which can be a threat or hazardous to the health and safety of construction workers. The client must take responsible steps to make sure that every principal contractor's health and safety plans as gritty in regulation are implemented and maintained on construction sites. The client shall ensure that if there are changes to specification and method of construction, sufficient health and safety information and suitable resources should be obtainable for the principal contractor so that the work can be executed safely. The client shall make sure that the prospective principal contractor during submission of tenders have made provision for all the cost of health and safety procedures during the construction method. The client also need to ensure that each principal contractor is registered and in noble position with the compensation fund as well as with a licensed compensation insurer prior to the work starting on site. The designer's input may be required at various stages of construction for better document preparation geared towards ensuring health and safety of construction workers. The designers also need to specify the products or materials that may constitute hazard and health risk during the construction period.

3 Research Methodology

This study is designed to obtain information on the level of importance of various safety guidelines on construction sites. Survey design was adopted with the aim of obtaining information from the respondents. The professionals involved in the study include architects, quantity surveyors, engineers, construction managers and construction project managers on various construction sites located in Gauteng region of South Africa.

Data for this research was collected from both primary and secondary sources. The primary data was collected by the use of questionnaires based on the secondary data obtained from existing literature materials. The secondary data helped in the construction of questionnaire. The questionnaire was designed as a structured closed-ended type and 50 of them were administered based on the availability of identified group of participants. For ethical consideration, respondents were treated as self-governing representative and their personal information were not revealed to the public. This was ensured by excluding confidential and private related questions from the demographic section of the questionnaire, which forms the first part of the instrument. The second part of the questionnaire was designed to understand awareness of respondents on three areas of safety guidelines, which include measures to control risk of fall from heights, ways to prevent injuries and improve safety as well as different ways to ensure compliance with provision of safety Act.

Data collected for this research was analyzed using descriptive statistical methods. 5-point Likert scale was adopted to determine the importance of various identified factors. The first set of scale includes 1 – Strongly disagree, 2 – Disagree, 3 – Neutral, 4 – Agree and 5 – Strongly agree. The second scale and their meaning include 1 – Very low, 2 – Low, 3 – Neutral, 4 – High and 5 – Very high. This five-point scale was converted to a mean item scores (MIS) and standard deviation (SD) for each of the factors using the formulae:

$$\mathrm{MIS} = \frac{1n1 + 2n2 + 3n3 + 4n4 + 5n5}{\sum N}$$

Where:
n1 = number of respondents for strongly disagree
n2 = number of respondents for disagree
n3 = number of respondents for neutral
n4 = number of respondents for agree
n5 = number of respondents for strongly agree
N = total number of respondents.

4 Findings and Discussion

From the distributed 50 questionnaires, 45 were returned and certified fit for further analysis. The analysis further reveals that 13 of them are quantity surveyors, 10 are engineers, 10 are project managers, 6 are architects, while 6 are construction managers. The respondents possess an average of about 8 years of experience in the construction industry, and are located in 6 metropolis of the region which include Akuruleni, Johannesburg, Metsweding, Sedibeng, Tshwane and West Rand.

The risk of fall from heights and their importance based on the opinions of relevant construction stakeholders are indicated in Table 1. From the mean item score (MIS) and the standard deviation (SD) values, control of the risk of falls by using advanced guard railing systems is the most important with a MIS of 4.49 and SD of 0.589. This is followed by control of the risk of external falls by consecutive erection (MIS of 4.24 and SD of 0.679), control of the risk of climbing falls with safe admission system (MIS of 4.22 and SD of 0.636), introduction of fall arrest and travel restriction systems (MIS of 4.18 and SD of 0.806), as well as control of the risk of internal falls by fully hitting (MIS of 4.13 and SD of 0.842). The finding supports study by the Commission for Occupational Safety and Health [14] of the Government of Western

Table 1. Measures to control risk of fall from heights.

Measures	MIS	SD	Rank
Control of the risk of falls by using advanced guard railing systems	4.49	0.589	1
Control of the risk of external falls by consecutive erection	4.24	0.679	2
Control of the risk of climbing falls with safe admission systems	4.22	0.636	3
Introduction of fall arrest and travel restriction systems	4.18	0.806	4
Control of the risk of internal falls	4.13	0.842	5

Australia, which stated that introducing fall arrests and travel restriction systems and controlling of the risk of internal falls by fully hitting are some of the key measures to control risk of fall from heights. More so, the Health and Safety Executive [16] concluded that providing the workers a safe means to work at height is an important consideration in the planning and execution of construction projects.

The Table 2 shows various ways to prevent injuries and improve safety on construction sites. Prevention and addressing of substance abuse by employees with a MIS of 4.62 and SD of 0.535 is the most important factor, this is followed by considering safety related issues during the project planning process with MIS of 4.62 and SD of 0.49. Other important factors include making safety a part of everyday conversation (MIS of 4.6 and SD of 0.539), review accidents and near misses as well as regular inspections (MIS of 4.53 and SD of 0.505). The findings further revealed the following as various ways of preventing injuries and improving safety on construction sites: making sure the workers are properly trained in appropriate areas; ensuring that the contractors are pre-qualified for safety; management of safety related issues; having a fall protection system; integrate safety as part of the job; and creating accountability at all levels. The highlighted measures are related to construction safety management, which support existing assertions that management of safety is one of the ways to prevent injuries on construction sites [1, 4, 13].

Table 2. Ways to prevent injuries and improve safety.

Variables	MIS	SD	R
Take safety into account during the project planning process	4.62	0.490	1
Prevent and address substance abuse by employees	4.62	0.535	2
Make safety a part of everyday conversation	4.60	0.539	3
Review accidents and near misses, as well as regular inspections	4.53	0.505	4
Make sure the workers are properly trained inappropriate areas	4.42	0.583	5
Make sure the contractors are pre-qualified for safety	4.42	0.583	5
Management safety	4.40	0.539	7
Have a fall protection system	4.38	0.614	8
Integrate safety management as part of the job	4.38	0.614	8
Create accountability at all levels	4.29	0.626	10

To guarantee safety on construction sites, Table 3 shows various ways ensuring compliance with provisions of the safety Act, which were earlier discussed in Sect. 2 of this paper. The most important measure is that the client shall take responsible steps to make sure that every principal contractor's health and safety plan as determined in sub regulation is implemented and maintained on construction sites (MIS of 4.38 and SD of 0.650). The client shall also appoint each principal contractor in the form of writing for the project on construction site (MIS of 4.33 and SD of 0.603), and stop work that is not in accordance with the health and safety plan (MIS of 4.33 and SD of 0.769). Furthermore, the client shall make sure that principal contractors (PCs) have made provision for the Health and Safety (H&S) costs in their tenders (MIS of 4.31 and SD of 0.633), as well as prepare a documented Health and Safety (H&S) specification for the construction work (MIS of 4.22 and SD of 0.850). To ensure compliance with

Table 3. Ways to ensure compliance with provision of safety act.

Measures	MIS	SD	Rank
The client shall take responsible steps to make sure that every principal contractor's health and safety plan as determined in sub regulation is implemented and maintained on construction sites	4.38	0.650	1
The client shall appoint each principal contractor in the form of writing for the project on construction site	4.33	0.603	2
The client shall stop work that is not in accordance with the health and safety plan	4.33	0.769	3
The client shall make sure that principal contractors (PCs) have made provision for the Health and Safety (H&S) costs in their tenders	4.31	0.633	4
The client shall prepare a documented Health and Safety (H&S) specification for the construction work	4.22	0.850	5

provision of safety Acts, health and safety plan implementation is the most important measure expected of construction clients. More so, all the identified measures were deemed important in ensuring compliance with the safety Act, which is in line with various construction regulations [5, 15].

5 Conclusion and Recommendation

The requirement for safety of lives and properties has been a major concern for individuals, government and relevant agencies. In the construction industry, various countries have domesticated health and safety regulations with a view to preventing injuries, accidents and the likes on construction sites. This study therefore examined the level of importance attached to various measures for ensuring compliance to health and safety rules on construction sites. To achieve the objective of the study, three areas of compliance to safety guidelines were considered, which include measures to control risk of fall from heights, ways to prevent injuries and improve safety as well as different ways to ensure compliance with provision of safety Act.

On the risks of fall, external, internal, climbing and general falls were considered. However, the most important measure is the adoption of advanced guard railing system to guide against risk of falls from heights. Consecutive erection of building members is required for controlling risk of external fall while the use of fully hitting system is the appropriate way to control risk of internal fall. Risk of climbing falls is best controlled by using safe admission systems while introduction of fall arrest and travel restriction systems was also deemed important measure for controlling risk if fall from heights.

Another area considered are the ways to prevent injuries and improve safety. There is a need to address and subsequently address substance abuse by construction workers, especially artisans and workers that are directly involved in construction activities.

There is also a need to consider safety during the planning and preconstruction phase of construction project, this will help in the review of accident through regular inspection, thereby making safety issues everyday conversation. The contractors should have necessary safety measures and this can be ensured by including and enforcing safety requirements as part of prequalification requirements.

The responsibilities of construction clients as well as their representatives – that is, construction professionals - in ensuring compliance with provision of safety Act were also discussed. The findings of this study indicates that there is a high level of importance of safety measures and guidelines among construction stakeholders. However, there is a need for enforcement of safety regulations with a view to improving health and safety of lives and properties. There is a need for construction projects' management commitment to safety as this is a drive for other measures. There is also a need for good vertical and horizontal communication among employees and management staff to promote good safety culture. Regular safety meetings should be organized where such things as improve safety technology, safety records for each operative, regular safety inspections and ban on abuse of substance including alcohol at work, should be discussed.

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Usability of Machinery

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Abstract. In our interrelated world with global market the responsibility and hence the potential to improve machinery safety lays on several actors including designers, manufacturers, end users and regulatory, standardization, representative, lobby organizations. On one hand according to the "free movement of goods" concept machinery safety is regulated like the safety of other products, including involvement of notified bodies, conformity assessment and international standards with mandatory requirements. On the other hand the provision of a safe and healthy workplace is a well respected value therefore national regulations are there on the use of tools including machinery in workplaces by workers. In both area the basic concept of safety is the management of risk, but the two approaches differ due to the differences in the quantity and diversity of machinery handled and due to the knowledge on target group and on the use. Although there several ways to link design and usage including e.g. standardization, acquisition, user-oriented design, the risk of machinery at the workplaces is not eliminated and workplace accidents with machinery still occur. This paper shows how risk assessment at workplaces and risk assessment in machinery safety should be connected, how knowledge of workers can be utilized in the design and how in general usability methodology evolved in software ergonomics can be applied in machinery design to improve workplace safety.

Keywords: Machinery safety · Usability inherently safe design · Inherently safe design · Foreseeable behavior · Ergonomics standards · CERA

1 Introduction

The U.S. Bureau of Labor Statistics reported 59,830 nonfatal occupational injuries and illnesses involving days away from work in 2015 where machinery was identified as the source of injury or illness (Table 1) [1]. Work equipments, including hand tools and machinery was responsible for more than 100.000 injuries or illness just in the US in a single year.

European statistics on accidents at work (ESAW) [2] show that fatal accidents due to working equipments including operating machine and working with hand-held tools happen relatively rare, but the total number of fatalities is still over hundred in the EU (Table 2). Accidents with machinery leading to more than tree days away from work happened 40,918 times. Both table include incidence rates of accidents interpreted as the number of accidents per 100,000 workers in a year period.

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Table 1. Number, incidence rate, and median days away from work for nonfatal occupational injuries and illnesses involving days away from work, US 2015

Source of injury or illness	Number	Incidence rate	Median days away from work
Machinery	59,830	54	7
Hand tools	52,030	47	5

Table 2. Workplace accidents in Manufacturing in the European Union (28 countries) in 2014

	Operating machine		Working with hand-held tools		Total	
	Number	Incidence rate	Number	Incidence rate	Number	Incidence rate
Fatal	71	0.22	29	0.09	574	1.78
4 or over days away from work	40,918	127.03	51,671	160.41	619,921	1,924.5

Boy and Limou [3] gave several examples when labor inspectors and other public authorities or notified bodies found machinery used in workplaces non meeting essential safety and health requirements. This study also suggest that these cases are not special and manufacturers frequently neglect requirements.

Although criteria used in the Composite Ergonomics Risk Assessment CERA [4] implement safety and health requirements laid down in harmonized standards, and should be assessed and decreased in the design process, just a few risk assessment ended without any reds. CERA was created to assess ergonomic risks resulted from bad postures [5], manual handling [6], force extension [7] and repetitive movements [8] at workplaces. The risk is unacceptable almost at every machine handling operation due to bad postures and these twisted/tilted/awkward postures act as contributing factors of other ergonomic risk decreasing the acceptable manual lifting weight limit or force limits or movement frequency. Since the EN 1005 standard series contains several independent assessment neither CERA provide a final score, but sums the number of greens/yellows and reds according to the relevant risks. CERA become popular in Hungary and was used for hundreds time. The shocking experience is that the question is not whether the workstation is acceptable or needs improvement but the number of reds, or how to explain to employers that the tool they are using shouldn't be installed at the first place due to the lack of compliance of health and safety requirements of machinery.

Several manufacturers work in close collaboration with their consumers, register every piece of machinery sold and its operators, the designer knows the real user behavior and this knowledge is fed to the design process and applied. Although the best collaboration should be expected when the personnel responsible for the safety in design and the personnel responsible for the operational, the workplace safety, is the same, these in-house machinery productions often lead to shortcuts, and some requirements is omitted like no conformity assessment is made or no technical documentation is done.

In real designing for human error is not easy partly because that errors are hard to predict partly because the use proper methods requires extensive expertise and are too expensive for non safety-critical cases [9]. The number of accidents related to machinery at workplaces and the wide spectrum of practices and examples of non-conformities should mean that the link between the design and use is random and indirect, and information on use required in the design phase is not accessible or incomplete.

2 Design and Operation

The ILO code of practice on Safety and health in the use of machinery fits together design and operational phases [10]. The life cycle of a machine starts on the left with design and ends on the right with decommissioning. Designers, suppliers and manufacturers are the key actors on the production side while workers play the user role and employers bear responsibility for safety on the operational side.

The code of practice expects designers, manufacturers, suppliers, employers, workers and their representatives to cooperate actively on safety and health in the use of machinery. The information of malfunctions, dangerous occurrences and accidents and diseases should be collected, reported at the workplace and feed back to designers likewise any new risks and measures taken to control end prevent recurrences. This gathered information on accidents and diseases is supposed to help manufacturers and designers to understand their product, users, the use, hazards better and should be used to improve the safety of machinery. The information provided from the feedback from workplaces allow designers to conduct a proper determination of limits of the machinery required by the mandatory risk assessment, covering the full range of uses of their machinery including the intended use and any reasonably foreseeable misuse as well.

3 European Regulations

In the European Union the Machinery directive regulates the machinery market according to the single market concept [11]. This directive requires all member states to operate the same processes and use the very same safety and healthy requirements when assessing safety of machinery. Core element of the directive are the conformity assessment, the involvement of notified (independent, assigned, registered) bodies, the CE mark with the declaration of conformity and harmonized standards. Harmonized standards are adopted by a European standardization body (CEN, CENELEC or ETSI) and published in the Official Journal of the European Union [12]. These standards are not binding but the safety and health level they require must be met. Over 700 Type C standards deal with defined types of machinery and describe detailed specific safety requirements. Type B standards like the EN 1005 covers specific aspects of machinery safety or contain safety requirements applicable in several types of machinery. For every type of machinery set requirements the single type A standard EN ISO 12100:2010 Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100:2010) [13].

The essential health and safety requirements relating to the design and construction of machinery laid down in this directive adopt the provisions of EN ISO 12100-1:2003 when as part of the risk assessment requires the identification of intended use and any reasonably foreseeable misuse of the machinery, and the hazards that can be generated by the machinery and the associated hazardous situations. According to the directive 'intended use' means the use of machinery as planed and documented in the instructions for use and reasonably foreseeable misuse' means other ways of use which may result from readily predictable human behavior. Principles of safety integration of the directive states that risk not only related to the conditions foreseen but also to reasonably foreseeable misuse should be prevented and the remaining risks communicated [11].

In the EU the CE mark represents the marketability including the conformity and the ability to use at workplaces as work tool (Fig. 1).

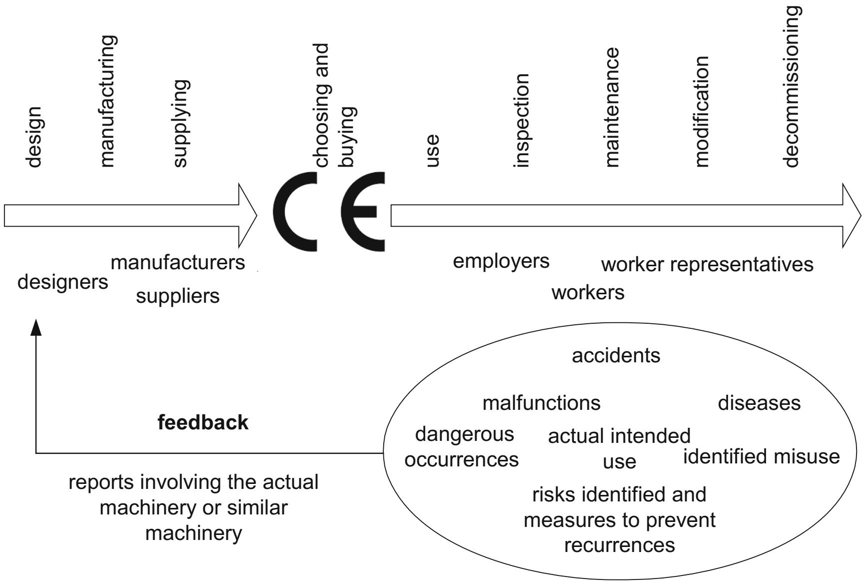

Fig. 1. Design and operational phases of machinery

The regulation on occupational health and safety matters follows a leveling approach, and member states have different legislations. The frame directive [14] and several other directives defines minimum requirements e.g. workplaces [15], fishing vessels [16], work with display screen equipment [17]. The directive on work equipment by workers [18] set obligations on employers and workers, and contains minimum requirements to work equipments. 'Work equipment' means here : any machine, apparatus, tool or installation used at work, and the 'use of work equipment' means activities like starting or stopping the equipment, its use, transport, repair, modification, maintenance and servicing, including, in particular, cleaning.

Performing the risk assessment required by the frame directive these minimum requirements often used in hazard identification.

The feedback from the workplaces to the manufacturers only provided through the market surveillance process, but no direct link required like the involvement of manufacturers in accident investigation or worker surveys on the use of machinery.

4 Human Machine Interface

The EU-OSHA report on the human machine interface (HMI) as an emerging risk summarized that field studies are needed to understand organizational and environmental factors to reduce the risk related to human machine interfaces. It states that usability engineering not recognized despite the it's competitive advantage, and users are involved mostly is validation tests Steps to be taken are e.g. [19].

- improvement and harmonization of accident investigation and reporting,
- usability tests should be applied and extended beyond normal operation, including emergency situations,
- understanding the specifics of various worker groups,
- improving user-friendliness systems,
- determination of the financial consequences of optimal HMI,
- developers, users and suppliers must increase collaboration.

The definition of 'usability' means the ability of a machine to be easily used owing to, among others, properties or characteristics that enable its function(s) to be easily understood [13]. The definition of usability is broader however. Usability also means 'the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use' [20], likewise foreseeable use means the "use of a product that is capable of being known or anticipated in advance based on a supplier's best knowledge about the product" in the consumer product safety approach [21]. These differences should be bridged and the broader usability approach implemented to guarantee the safe design aimed by the user feedback.

The responsibility for identification of all plausible scenarios can easily be omitted when the manufacturer conducts the assessment and issues the declaration of conformity not being aware several other relevant harmonized standards. When approval authority are involved the type approval procedure lays the responsibility primarily with them, so and designers are not forced to consider the implications of their design [22].

By using a participatory design paradigm, manufacturers can understand user needs from the start of the design process, e.g. use-ware-methods was adapted from web-design by consumer industry, and later penetrated industrial areas [23].

5 Feedback Method

The new EN 16710-2 Ergonomics methods – Part 2: A methodology for work analysis to support design [23] provide a methodology and framework to analyze and understand end users' performance with machineries. The work system is describe with the work activity in focus, and thanks to the system approach it contains both technical and human inputs on the left and outputs on the right (Fig. 2) technical and organizational means (e.g. machinery, premises, work organization, maintenance policy) and personal resources (e.g. age, gender, training), economic performance results (quantitative or qualitative) and positive-negative/short term/long term effects on worker (e.g. performance, health, safety) respectively.

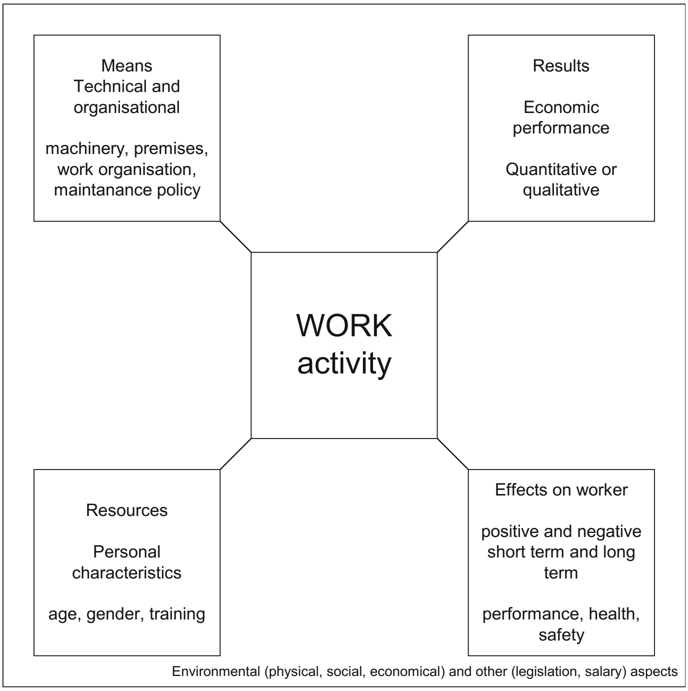

Fig. 2. "The activity focused work system" based on EN 16710-2

A recent European technical report describes the Feedback method to understand how end users perform their work with machines [24]. The feedback method is a structured way to solicit skilled workers opinion [25]. The under laying idea is that some workers have training and work experience on the installation, operation, maintenance of the machinery in question and their knowledge can be distilled and documented in a standardized way. The process mentioned lead by a specialist trough the following steps:

- preparation, collection of information related to the machine in question,
- observation of workplaces where this machine is used,
- structured interview with skilled workers,
- result validation,
- documentation.

The observation aims all the feed back elements suggested in the Design and operational phases of machinery (Fig. 1) and covers all aspects mentioned in the "activity focused work system" (Fig. 2) including all work phases in details from normal operation

to unplanned maintenance. Signs of misuse can be identified by gathering information on near-misses and accidents with the machine.
Some application show that the feedback method can be used to

- identify design errors or errors of existing standard in the design stage,
- verify and validate existing results,
- monitoring work efficiencies [25].

Based on the work analysis a group of skilled workers reconstructs the work activity and carries out a systematic analysis of each work activity producing e.g. a list of critical aspects of the machinery.

6 Conclusion

In spite of the effort made to reduce serious workplace accidents due to machinery use still happen. Wrong operator behavior is one of the frequently identified root causes of accidents. On the other hand wrong worker behavior means unidentified possible operators actions or the omission of foreseeing the operator behavior.

Harmonized standards on methods to collect data of use of equipments used in workplaces by workers to help designers understand the real use should improve risk assessments and leading to safer and healthier products.

There is no denying that like the feedback method usability methods are time and labor-intensive, but they allow designers to predict operator's activity and make a safer machinery such decreasing the equipment related risks at workplaces.

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Contributory Factors Analysis on Undergraduates' Unsafe Acts at University

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Abstract. In order to prevent accidents related to undergraduates on campus, contributory factors of undergraduates' unsafe acts were analyzed. By conducting a survey and data analysis, factors leading to unsafe acts and quantitative relationship among these factors and unsafe acts were studied. A structural equation model (SEM) expressing causes to unsafe acts was built. The results showed that university safety investment, university safety management, safety awareness of undergraduates and influences from their family had direct impacts on unsafe acts of undergraduates, and safety awareness had the most significant impact. It was also revealed that safety training at university, safety education at secondary school, relationship among students had indirect or less influence on preventing undergraduates' unsafe acts.

Keywords: Unsafe acts · Undergraduates · Contributory factors · Safety awareness

1 Introduction

Accidents among undergraduates at universities aroused widespread concern in public. It is found that unsafe acts of undergraduates are main causes to these accidents, and preventing undergraduates' unsafe acts is an effective intervention to accidents on campus [1]. Therefore, it is of significance to study on the contributory factors leading to unsafe acts of undergraduates.

Some researchers argue that unsafe behaviors of workers are caused by both individual factors (e.g. physical, psychological, knowledge and skills) and external (or objective) factors (e.g. environment, organizational management) [2]. Other researchers believe that internal factors leading to employees' unsafe behavior include personality traits, safety awareness on site, safety knowledge and safety competence. External factors are considered to be a combination of organizational factors, environmental factors and leadership factors [3].

Wang Yonggang etc. develop a structural equation model to show the contributing factors to employees' unsafe acts, which indicates that internal factors include experience, attention and memorizing ability; and external factors include work task, team management and system characteristics [4]. In coal and mining industry, causes to people's unsafe behavior are summarized to human physiological factors, psychological factors, human-machine matching factors, safety management, safety culture, personal

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life events [5]. Guo Binbin points out that the factors which affect the unsafe behavior of miners in China include safety climate, personal factors, work pressure and work environment [6]. Choudhry concludes that the leading factors to employees' unsafe behaviors in construction industry include organizational management, safety procedures, psychological characteristics, self-esteem, work experience, work performance measurement pressure, risk awareness, work environment, safety training etc. [7].

At present, research methods on contribution factors to unsafe behaviors are mainly questionnaires, interviews, and literature analysis. The data are normally analyzed by SPSS, LISREL, SMART-PLS and AMOS [8–10].

The causing factors to unsafe behaviors are studied mainly in coal mining industry and civil aviation industry. The results of these studies show that contributing factors to unsafe acts vary in different industries. Up to now, there are few studies on contributory factors to unsafe acts of undergraduates. In this situation, the author tried to find out the influencing factors to undergraduates' unsafe acts by conducting surveys and data analysis.

2 Method

A questionnaire was developed in form of Likert Scale to find out the common unsafe acts of undergraduates and the possibly relating information. A SEM was designed to indicate the influencing factors of undergraduates' unsafe acts. SEM is a model that relies on empirical analysis to establish the structural relationship among variables and verify the rationality of the hypothesis. The process of SEM analysis has five steps, which are model setting, identification of the model, estimation of the model, model evaluation, and model revision.

2.1 Questionnaire

Through pre-survey, literature review, student interviews and expert interviews, safety awareness, safety management, safety investment, safety training, relations among undergraduates, safety culture, influence from family, and safety education received from secondary education were identified as main contributory factors to undergraduates' unsafe acts. These factors were summarized to four categories. The author designed several questions which could reflect each contributory factor (Table 1). The questionnaire had 41 questions, each of which had five answer choices (totally agree, agree, hard to say, disagree, totally disagree).

2.2 Data Collection

210 questionnaires were handed out and 196 were received, with a response rate of 93.33%. The sources of undergraduates who were enrolled to answer the questionnaire are shown in Table 2.

Table 1. Categories of contributory factors.

Contributory factors category	Contributory factors
Personal safety characteristics	Safety awareness; Safety knowledge
Factors relating to universities	Safety management; Safety investment; Safety education at university
Influences from classmates	Relationship among undergraduates; Safety culture
Growing up background	Influence from family; Safety education at secondary school

Table 2. Sources of the undergraduates who answered the questionnaire.

Grade	Sex	Number	Percentage %
One	Male	42	21.4
	Female	11	5.6
Two	Male	32	16.3
	Female	18	9.1
Three	Male	34	17.3
	Female	13	6.6
Four	Male	31	15.8
	Female	15	7.7
Total	Male	139	70.9
	Female	57	29.1

3 Results

3.1 Reliability and Validity Analysis of the Questionnaire

Cronbach's alpha, which is one of the most widely used indicators of reliability in the social and organizational sciences, was used in the reliability analysis. The criteria for Cronbach's alpha coefficient used in this research was shown Table 3.

Table 3. Criteria for Cronbach's alpha.

Cronbach's alpha	Internal consistency
$\alpha \leq 0.3$	Unacceptable
$0.3 \leq \alpha < 0.4$	Poor
$0.4 \leq \alpha < 0.5$	Questionable
$0.5 \leq \alpha < 0.7$	Acceptable
$0.7 \leq \alpha < 0.9$	Good
$\alpha \geq 0.9$	Excellent

SPSS program was used to analyze the reliability of the questionnaire. The internal consistencies of questions relating to safety awareness and student relationship were relatively low, but still within the range of the acceptance. All the other questions relating to other contributory factors held high internal consistencies (see Table 4).

Table 4. Reliability test of variables.

Variables (contributory factors)	Number of questions	α Value
Safety awareness	4	0.438
Safety knowledge	4	0.701
Safety management	4	0.827
Safety investment	3	0.714
Safety education at university	2	0.729
Relationship among undergraduates	4	0.456
Safety culture	4	0.721
Influence from family	4	0.776
Safety education at secondary school	4	0.818
Unsafe acts of undergraduates	8	0.777
Total	41	0.904

Exploratory factor analysis was used to verify the structural validity of the questionnaire, and KMO (Kaiser-Meyer-Olkin) test was applied to the contributory factor categories. Validity refers to the degree to which the measurement objective can accurately be measured by the questions. If KMO value is 0.9 or higher, it is very accurate; 0.8 means accurate; 0.7 means normal; 0.6 means inaccurate and 0.5 or less means inaccurate at all. The KMO values of the questionnaire were shown in Table 5.

Table 5. KMO values of four contributory factor categories and questions relating to unsafe acts.

Categories	KMO
Personal safety characteristics	0.687
Factors relating to universities	0.837
Influences from classmates	0.715
Growing up background	0.796
Unsafe acts	0.786

3.2 Assumptions for Developing SEM

The following assumptions were made for each contributory factors according to the way they might affect undergraduates' unsafe acts:

Personal safety characteristics:

H1: Undergraduates' safety knowledge had a positive impact on improving safety awareness.
H2: Undergraduates' safety awareness had a positive impact on reducing unsafe acts of undergraduates.

Factors relating to universities:

H3: Safety management at university had a positive impact on reducing unsafe acts of undergraduates.
H4: University's safety investment had a positive impact on reducing unsafe acts of undergraduates.
H5: Safety education had a positive impact on improving undergraduates' safety knowledge.

Influences from classmates:

H6: Good relationship among students had a positive impact on improving undergraduates' safety awareness.
H7: Positive safety culture had a positive impact on improving undergraduates' safety awareness.

Growing up background:

H8: Positive influences from family on safety had a positive impact on improving undergraduates' safety awareness.
H9: Positive influences from family on safety had a positive impact on reducing undergraduates' unsafe acts.
H10: Safety education in secondary school had a positive impact on improving undergraduates' safety knowledge.
H11: Safety education at the secondary level had a positive impact on reducing undergraduates' unsafe acts.

3.3 SEM Development

Before a SEM is used, it is necessary to verify whether the model meet the requirements to analyze the relationship among the contributory factors. Violation estimation is needed. Negative variance could not exist, and the normalization coefficient cannot exceed 1. The measurement error of the variance in the model was 0.044 to 0.135, and there was no negative variance. The normalization coefficients were in the range of 0.016 to 0.935, which did not exceed 1. Therefore, the model could be used for further analysis. AMOS software was used to design the SEM, and the parameters were tested to be full of requirements. The parameter values were shown in Table 6.

Table 6. Parameter values of the SEM developed.

Parameters	$\chi 2$/df	RMSEA	NFI	IFI	CFI
Value	2.847	0.058	0.873	0.832	0.854

The relationships among contributory factors were represented by a diagram, which was shown in Fig. 1.

An initial test was conducted about the initial SEM, the test results were shown in Table 7.

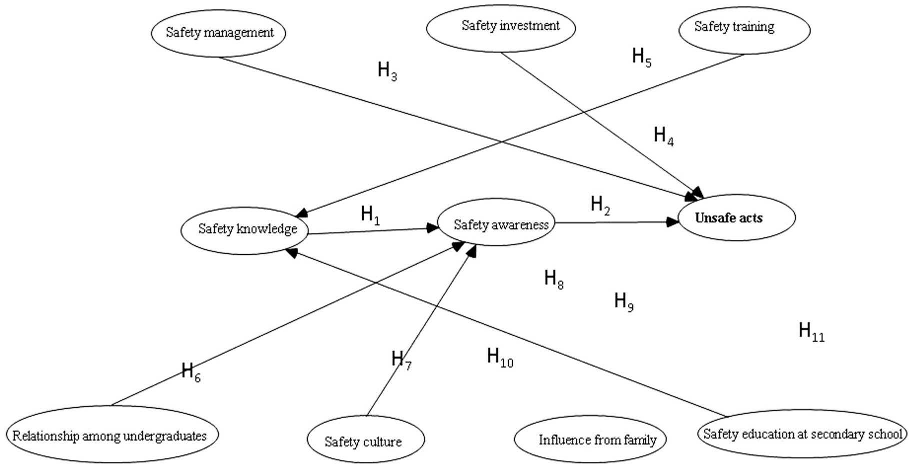

Fig. 1. Initial SEM.

Table 7. Test result of initial assumptions.

Assumption number	Influence routes	S.E.	C.R.	P
H_1	Safety knowledge → Safety awareness	0.128	2.449	***
H_2	Safety awareness → Unsafe acts	0.958	4.548	***
H_3	Safety management → Unsafe acts	0.461	5.827	***
H_4	Safety investment → Unsafe acts	0.226	2.713	0.007
H_5	Safety training → Safety knowledge	0.667	4.941	***
H_6	Relationship among undergraduates → Safety awareness	0.658	3.589	***
H_7	Safety culture → Safety awareness	0.258	3.529	***
H_8	Influence from family → Safety awareness	0.016	0.133	0.894
H_9	Influence from family → Unsafe acts	0.440	2.417	0.016
H_{10}	Safety education at secondary school → Safety knowledge	0.223	3.587	***
H_{11}	Safety education at secondary school → Unsafe acts	0.118	1.568	0.117

In this table, S.E. is the standard error of the parameter; C.R. is critical value; and P is the significance probability. *** means the significance probability is 0.000, which is less than 0.05.

The reference value of the C.R. was 1.96. It could be seen from Table 8 that the C.R. of 9 paths exceeded the critical value. And influence routes with a P less than 0.05 indicated that the routes passed the significance test. H8 and H11 held C.R. less than 1.96 and P greater than 0.05, which meant that these two influence routes did not pass the significance test.

Table 8. Value of relative parameters.

Parameters	χ2/df	RMSEA	NFI	IFI	CFI
Initial model	2.847	0.058	0.873	0.832	0.854
Revised model	2.789	0.051	0.804	0.896	0.903
Criteria	≤ 3	≤ 0.05	≥ 0.90	≥ 0.90	≥ 0.90
Analysis result	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

3.4 SEM Revision

There were two assumptions in the initial SEM that were not justified by the data, which were positive influence from family had a positive impact on safety awareness of undergraduates and the safety education in secondary schools had a positive impact on reducing the unsafe acts of undergraduates. These two assumption routes were deleted to make the model more accurate. A revised SEM was shown in Fig. 2.

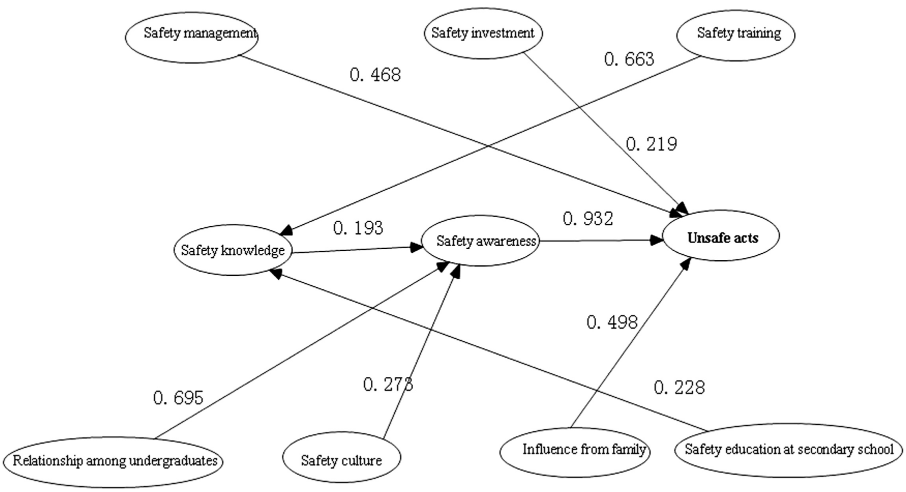

Fig. 2. Revised SEM.

The comparison between the revised model and the initial model was shown in Table 8. Compared with the initial model, the revised model was improved to be more reasonable.

4 Discussion

The final SEM had nine assumption routes. High safety awareness of undergraduates had a very positive impact on reducing unsafe acts. The relationship among students and safety culture could affect their safety awareness, which indirectly influenced the unsafe acts of undergraduates. Good relationships enabled undergraduates to care for and help each other so as to reduce unsafe acts. The safety training on students and the safety education that they accepted at secondary school could have direct impact on the safety knowledge of undergraduates and then improve their safety awareness to avoid unsafe acts. Safety management at university, safety investment and influences from family could directly affect the students' unsafe acts.

The correlation coefficient between high safety awareness and undergraduates' unsafe acts prevention was 0.932. The correlation coefficient between positive family influence and undergraduates' unsafe acts prevention was 0.498. Good safety management at university had positive impacts on preventing undergraduates' unsafe acts with a correlation coefficient of 0.468. The correlation coefficient between good safety training and improving undergraduates' safety knowledge was 0.663. Good relationship among undergraduates had a positive influence on improving undergraduates' safety awareness, and the correlation coefficient between them was 0.695.

The results indicated that safety awareness, influence from family, university safety management, safety training and students' relationship had great influence on undergraduates' unsafe act prevention. By contrast, safety investment of universities, safety education in secondary school and safety culture had less contribution to prevent unsafe acts of undergraduates.

5 Conclusions

To our knowledge, it was the first research on contributory factors to undergraduate's unsafe acts. The reliability and validity of the questionnaire were verified, and a SEM was established to express the influencing routes of each contributory factors. The main conclusions are as follows:

(1) There were mainly nine contributory factors to undergraduate unsafe acts, which were safety awareness; safety knowledge, safety management; safety investment; safety education at university, relationship among students; safety culture, influence from family and safety education at secondary school.

(2) These contributory factors shared different importance in their way to influence undergraduates' behavior on safety.

The number of respondents in this study was relatively limited, and more undergraduates from different universities were suggested to be involved in future research to improve the result.

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Analysis on Human Unsafe Acts Contributing to Falling Accidents in Construction Industry

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Abstract. Falling from high is an accident type with high frequency and high death rate in construction industry. It occupies nearly 60% of the total accidents in construction industry in China. Human factors contribute to most of this accident type. 56 accidents were analyzed utilizing 24 Model in this paper, which was an accident causation model developed by one of the author. 19 categories of unsafe acts were identified from the falling accident analysis. Unsafe acts involving both frontline workers and managers were studied. Moreover, 2 key unsafe acts, insufficient training on workers and defects on usage of safety belt or safety helmet, were identified to contribute to nearly 80% of the accident. The results provided guidelines to develop interventions for preventing falling accidents. Results obtained in this paper can be used by companies in their occupational safety strategies and design of safety training programs.

Keywords: Falling accident · Construction industry · Unsafe acts · 24 model

1 Introduction

Falls are highly frequent accidents in construction industry and occupational fatalities and injuries caused by falls from height pose a serious public problem worldwide. Falling accidents constitute 52.25% of the reported accidents in construction industry in China in 2016 [1]. A more comprehensive understanding of causal factors leading to fall incidents is essential to prevent falls in the construction industry.

Contributing factors to occupational fatal falls are identified with respect to the victim's individual factors, the fall site, company size, and cause of fall by Chi et al. [2]. Falling accident are classified to several patterns, and causes to each falling accident patterns are analyzed. Among the causes, bodily action is pointed out to be a contributing factor. However, no concrete unsafe act is analyzed.

Chi et al. present accident causes associated with each falling site as a fault tree to provide an overview of the basic causes, which could trigger fall fatalities in the construction industry [3]. A decision trees analysis of construction falling accidents involving roofers was constructed to extract rules that show the associations between attributes for roofer fall accidents. [4] The results showed that fatality chances

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increased with increasing fall distance and decreased when safety training was provided. The most important input attributes in the models were identified as the fall distance, fatality/injury cause, safety training, and construction operation prompting fall. Kun Hu etc. point out that factors commonly associated with falls included working surfaces and platforms, workers' safety behaviors and attitudes, and construction structure and facilities [5].

To our knowledge, most of the research are on the relationship between attributes and falling accidents and no research is on the specific unsafe acts analysis. This paper aims to find out the what unsafe acts lead to falling accidents and their frequency, which may be beneficial for design safety training for mangers and frontline workers to prevent future unsafe acts.

Different types of studies including surveys, interviews, questionnaires, case studies, accident/incident records, observations and controlled laboratory experiments in various disciplines have been conducted to elaborate contributing factors. And learning from the past is a good way to find out what we want. So, case study was adopted as the research method in this paper.

The methods that researchers use to analyze accidents are critical to aid our understanding of causes. 24 Model was developed from the view of behavior safety by Fu et al. [6]. It is easy to use in analyzing unsafe acts leading to accidents. And, some valuable conclusions have been get using this model. Study on Unsafe Acts of Explosives Spontaneous Combustion Accidents in Underground Coal Mines and mine blasting provide valuable information on identifying specific interventions for preventing unsafe acts by workers and managers [7, 8]. Therefore, in the paper, the authors provided an analysis on contributing unsafe acts to falling accidents through analyzing falling cases on construction sites.

2 Methods

56 accidents from 2000 to 2016 were collected from internet or books published. The information of these 56 accidents were all accident reports from the government. These accidents were analyzed in detail using 24 Model. 3 researchers analyzed the 56 accidents separately. After they finished all the analysis, a group discussion was conducted to get an agreement on the result.

In the process of analyzing, causes are described into four types, which are root cause, radical cause, indirect cause and direct causes (see Fig. 1). Direct causes include unsafe acts and unsafe conditions. Both unsafe acts from front-line workers and their managers are identified. These indirect causes related to individuals are consequences of defects of organizations, which are inadequate safety culture and faults in safety management system. Safety management system include necessary documents and safety management human resources.

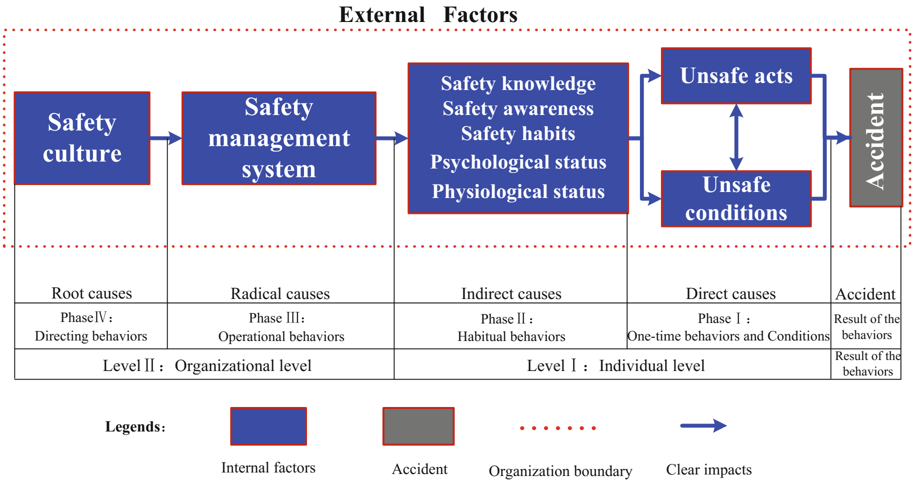

Fig. 1. Framework of 24 Model [6].

24 Model was adopted in this paper because of the following two reasons. Firstly, 24 Model is suitable for analyzing accidents related to systems which are not very complicated. Normally, the mechanical systems on construction site are not very complex. And, without much decision making occasions, what people should do is normally complying with fixed procedures. Secondly, accidents in construction industry are dominantly caused by human behaviors. And, 24 Model analyzes accidents based on behavior safety theories.

Since, we focused on unsafe acts in this paper. Only part of the analyzing results, direct causes part, was used in this research.

3 Results and Discussion

We got 296 unsafe acts in total. 213 unsafe acts were conducted by managers, whereas 83 unsafe acts were from front-line workers. There were 5 unsafe acts in each accident occurrence in average. These 296 unsafe acts were classified into19 categories. There were certain category of unsafe acts, such as failure to follow the construction organization design, might be conducted by either workers or managers. In this paper, managers meant people did not directly work with equipment. They usually did paper work, organization or supervision.

The frequency of unsafe acts were shown in Table 1. The order of unsafe acts was arranged according to the frequency of its occurrence.

Table 1. Unsafe acts categories and their frequency of occurrence

No.	Unsafe acts	Freq.	%	Freq. from managers	Freq. from frontline workers
1	Defects on safety training	43	77%	43	0
2	Without or improper use of PPE	43	77%	0	43
3	Failure to follow the construction organization design	23	41%	6	17
4	Defects on safety instruction before work	22	39%	22	0
5	Failure to eliminate the hazards	22	39%	22	0
6	Inadequate safety supervision on site	19	34%	19	0
7	Defects on routine safety check	18	32%	18	0
8	Assign unqualified worker to do special work	16	29%	16	0
9	Unqualified to do some special work	14	25%	3	11
10	Stay or walk in a dangerous area or in a dangerous manner	13	23%	0	13
11	Not promptly stop staff violations	12	21%	12	0
12	Defects on safety inspection and acceptance	12	21%	12	0
13	Without qualified safety protection facilities	9	16%	6	3
14	Illegal subcontracting	9	16%	9	0
15	Ask staff to take risks	8	14%	8	0
16	Fail to encourage workers to follow safety rules and regulations	5	9%	5	0
17	Illegal start of construction project	4	7%	4	0
18	Use equipment with hazards	3	5%	3	0
19	Drink before work	1	2%	1	0

(1) Defects on safety training

The top two categories of unsafe acts were defects on safety training and application of PPE (safety belt and safety helmet). These two categories of unsafe acts shared the same frequency. There were two situations of defects on safety training. The first situation was no safety training was provided, and the other one was no effective or adequate safety training was provided. The difference between defects of safety training on managers and workers were also analyzed. We could know from the result that safety training on managers normally were implemented, however safety training on workers were more often to be neglected. And, inadequate safety training occurrence frequency was nearly the same as the safety training absence occurrence frequency (Table 2).

Table 2. Sub-categories of defects on safety training and their frequency

Sub-categories of defects on safety training	Freq.	%
Inadequate safety training to managers	3	5
Inadequate safety training to workers	19	34
No safety training provided to workers	20	36
No safety training provided to managers	1	2

(2) Without or improper use of PPE
Another important contributing factors leading to falling accidents in construction is without or improper use of PPE, which are safety belt and safety helmet. Safety belt and safety helmet are both necessary for working at height. However, working without either safety belt or safety helmet and working with neither of them lead to 51% of the 56 accidents. And, working without safety belt occurred with a much higher frequency than working without safety helmet. Incorrect use of safety belts caused 11% of the accidents. Working without PPE was sometimes because no PPE was provided, which was with a percentage of 7% (Table 3).

Table 3. Sub-categories of without or improper use of PPE and their frequency

Sub-categories of without or improper use of PPE	Freq.	%
Work without safety belt	17	30
Work without safety helmet	3	5
Work without both safety belt and safety helmet	9	16
Incorrect usage of safety belt	6	11
Unqualified PPE was provided	4	7
No PPE was provided	4	7

(3) Failure to follow the construction organization design
This unsafe acts occurred 23 times in these 56 accident, which was a quite a high frequency. 6 of this unsafe acts were organized by managers, and 17 of them were conducted by front line workers. This factor was usually identified in accidents which caused more than one death. Workers might start work before necessary safety facilities were installed. Or, the necessary facilities did not meet the design requirements.

(4) Defects on safety instruction before work
Safety instruction before work is a very important document, which is legally required in China. Managers should delivered the safety instruction before work to all the workers and signatures of workers are required to certify that they was told about the safety instruction. In 15 accidents, workers did not received safety instruction before work, and workers did not receive adequate safety instruction in 7 accidents (Table 4).

Table 4. Sub-categories defects on safety instruction before work and their frequency

Sub-categories of unsafe acts relating to safety instruction before work	Freq.	%
Inadequate safety instruction before work	7	13
No safety instruction document	15	27

(5) Failure to eliminate the hazards
There are safety check or hazard identification during the construction work. A follow-up hazard elimination should be done if hazards are identified. However, there were 39% of the accidents are partly caused by failure to eliminate hazards timely.

(6) Inadequate safety supervision on site
Lack for supervision on site also contributed to many falling accidents (34%). The competence and conscientiousness of supervisors on site influenced the result of safety supervision. And there was another situation, which was that no supervisor was assigned on site (Table 5).

Table 5. Sub-categories of inadequate safety supervision on site and their frequency

Unsafe acts	Freq.	%
Inadequate safety supervision on site	16	29
No safety supervisor on site	3	5

(7) Defects on routine safety check
Routine safety checking is an effective way to identify hazards and correct violations. Nearly 20% of the accidents had problem on safety checks. In 11 accidents, managers did not conduct safety check, and there was a big mistake in safety check in the other one accident (Table 6).

Table 6. Sub-categories of defects on routine safety check and their frequency

Sub-categories of defects on routine safety check	Freq.	%
Did not conduct safety check	11	20
There is a big mistake in safety check	1	2

(8) Assign unqualified worker to do special work
In nearly 30% of these accidents, managers assigned unqualified worker to do special work, which required workers to attend special training and get a certificate.

(9) Unqualified to do some special work
There were 3 managers who were not qualified to be mangers of a project. And, 11 workers did work without necessary qualification. Lack of knowledge on their work lead to falling accidents directly or indirectly.

(10) Stay or walk in a dangerous area or in a dangerous manner
Workers sometimes stayed or walked in dangerous areas to take a short cut or avoid inconvenience. And, some workers had a unsafe habit to walk which might be because they did not know the hazard to doing so (Table 7).

Table 7. Sub-categories of Stay or walk in a dangerous area or in a dangerous manner and their frequency

Sub-categories of Stay or walk in a dangerous area or in a dangerous manner	Freq.	%
Stay or walk in a dangerous area	10	18
Walk in a dangerous way, for example, walk backwards	2	4
Climb with too many tools in hands	1	2

(11) Not promptly stop staff violations
Supervision is a common way to prevent workers' unsafe behavior. There were 21% of these 56 accidents were caused by not promptly stopping workers violations. This situation might be because of the knowledge, attitude or awareness of the supervisors.

(12) Defects on safety inspection and acceptance
Safety inspection and acceptance was required after some construction process was finished. Contributory factors that safety inspections were not carried out or there were flaws in safety inspection and acceptance occurred in 21% of the accidents.

(13) Without qualified safety protection facilities
Safety facilities, such as safety fence should be used while working in a high place. However, 21% of these 56 accidents had causal factors relating to inadequate safety protection facilities. And, 2/3 of these unsafe acts were conducted by managers, and 1/3 were conducted by workers.

(14) Illegal subcontracting
Illegal subcontracting meant asking organizations that are not eligible to do some work to do the project. This unsafe act was decision from managers. Illegal subcontracting contributed to 16% of the accidents.

(15) Ask workers work with hazards
Normally, workers followed instructions from their managers. However, there were 14% of the accidents led by violations of asking workers to work with hazards.

(16) Fail to encourage workers to follow safety rules and regulations
There is a responsibility for managers to encourage workers to follow the safety rules and regulations. However, some managers in these accidents did not do anything on it in their normal work. This unsafe act of managers led to 9% of the accidents.

(17) Illegal start of construction project
Some projects started without of a permission from the government. These projects usually did not fulfill requirements on safety.

(18) Use equipment with hazards
Sometimes, workers did not check the situation of the equipment. And, some workers might keep on using equipment with hazards because of low safety conscious.

(19) Drink before work
There was one accident caused by a worker who drank alcohol before work, which is strictly forbidden. Workers definitely know the risk of drinking before work, however, there are still someone did it. It may require more education and supervision on it.

4 Conclusions

Unsafe acts contributing to falling accidents were discussed by analyzing 56 accidents using 2–4 model. Both unsafe acts caused by managers and workers were studied and classified. The results could benefit the design of falling accident preventing measures. More causes from systematic view could be studied in future work to work out more suggestions on preventing falls in construction industry.

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Study of the Influence of Training in Occupational Safety and Health in the Human Factors of the Construction Sector

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Abstract. In the international context, the issue of Occupational Safety and Health (OSH) in the Civil Construction sector is still a problem related to a lack of safety culture, lack of resources and means, short implementation times, lack of effective supervision, the lack of basic or sectoral training of some actors in this industry, among other causes. Construction accidents cause many human tragedies, discourage workers, interrupt the construction process, adversely affect the costs, productivity and reputation of this industry and slow down the progress of society (*Integrating Safety and Health Performance into Construction*, 1997). Portugal is one of the countries of the European Union that has one of the highest labor loss rates, with a higher incidence in the Civil Construction sector. The importance of this sector to the Portuguese economy is very well known, since it is a direct source of employment of workers. Its activity moves several sectors, upstream and downstream of its production chain, which is why it is considered one of the driving forces of the national economy, not only because of its specific weight in wealth creation but also in employment, taking into account the Its obvious multiplier effect, and is therefore a fundamental activity for the growth of the economy. This is a sector with a low-skilled workforce, presenting a great precariousness and job instability, offering low salaries and demanding high levels of income. It is also characterized by a large and constant displacement of personnel from site to site, who are also required a frequent change of place and job within each work. It also requires a great deal of versatility on the part of workers in that it has a huge diversity of activities and professions. Therefore it is urgent to change this paradigm, in favor of occupational safety and prevention.

Keywords: Construction · Prevention · Sinistrality · Formation · Investment

1 Introduction

Construction has a set of very specific and unique characteristics, which are associated with a strong precariousness and labor turnover, plus the general practice of

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subcontracting. These peculiarities give it a unique character among the different sectors of economic activity and transform it into one of the ones that present a higher accident rate, especially with regard to fatal accidents. For this reason it deserves careful attention [1].

It is recalled that in the construction industry, the construction process does not take place around the machine, as a static logic of factory scope, but rather as a function of the dynamics of the project that is carried out. It follows that prevention must be developed according to its own methodologies that accompany the dynamics and particularities of projects and construction processes [2].

The performance of OSH should be a priority of all corporate hierarchies, as well as in the framing, planning and execution of works, ultimately reaching the workers, also responsible for their self-control as regards their prevention as key players in the process productive activity of the construction industry, which due to the activities they carry out are exposed to several specific high risks of this sector.

It will be important to analyze the level of basic training (level of education) and level of training in OSH.

These elements are fundamental throughout the organizational structure. Given that they are the link between Safety Technicians and workers, and can become the largest agent in promoting and implementing prevention in companies/works.

Identify the role of Intermediate Managers in the organics of the organizations, using several management tools that will allow planning, organizing and controlling the results of the Team, always focusing on the productive area and OSH [6].

Investing in the training of intermediate managers will, in the short and medium term, result in productive gains, reduction of accident rates, improvement of corporate image, valuation of “life”, reduction of income or work stoppages due to accidents [1].

In short, all direct and indirect costs associated with the incident/accident at work. It is important to gauge the impact of team leadership on the reduction of accident rates, the way in which its leadership is carried out, the relationship with training and professional experience.

Given the great mobility and turnover of workers, it can be seen on the ground that most of the operational workers “only” have OSH training, when they start an activity or a work, in fact “only” a meeting, often of little time, where the risks associated with the tasks to be performed are transmitted [2].

Also, in order to understand the opinion of the workers in the sector regarding health and safety issues in their workplace, and the aspects they would like to see improved, 416 workers’ surveys and 109 companies were administered in the sector, and through from its analysis it was possible to make some considerations about this theme.

2 Materials and Methods

The central objectives of the present study were to try to perceive, through the workers, opinions, the extent to which the two contracts that served as a sample show a concern with health and safety issues and to what extent they provide training/information sessions to all its workers.

This work had a methodological basis based on three fundamental bibliographical research components:

Scientific component - Consultation and analysis of several articles and scientific papers with peer review, as basis for framing and orientation of the theme and proposed objectives.
Legal component - Support and support in various legal and normative documents, both historical and current, in order to support the development of this work in the guidelines issued by the bodies that supervise and supervise the law and working conditions, both at the national level (ACT; ASAE; DGS; among others), either international (OIT; AESST; AISS; among others).
Technical component - Research and study of several statistical models, of treatment and data analysis.

The bibliographic research components were complemented with a statistical analysis of the behavior of the work accident in Construction that met the requirements identified as factors common to several organizations.

For this purpose, a data survey was carried out, with the latter as a base instrument for two questionnaires, which were submitted to a pre-test. The data were treated for statistical purposes in the present research work.

The questionnaires carried out in a real context of execution of two works (Figs. 1 and 2), that moved several sectors, upstream and downstream of its production chain. In both situations, the questionnaires were applied to a sample of 109 companies and 416 workers, in a total universe of 134 companies and 852 workers who participated in the entire production process.

Fig. 1. Construction of large sewage treatment plant.

Fig. 2. Construction of drainage networks for sewage and water supply

Notwithstanding the insistence, the sample resulted from the kindness and cooperation of the respondents who agreed to participate in the study.

The questionnaire was applied to the companies based on the following requirements:

- Companies with economic activity in the field of Civil Construction and Public Works, with different dimensions (staff, annual turnover, qualification, safety and medical services at work, investment in OSH and training provided to workers in OSH), within the period under study;
- Existence of accident records within the study period.

The application of the questionnaire to the workers was carried out based on the following requirements:

- Collection of personal data of the worker (professional category, age, gender, nationality, schooling);
- Collection of professional data of the worker (possessing CAP for the professional activity, professional situation, time practiced, time of activity in the company, time of experience in the current function, time of experience in the construction sector, family background in construction and data On OSH training) within the study period;
- Collection of information indicating how the accident occurred, the circumstances in which it occurred, and how the injuries occurred (the event is divided into three sequences: specific physical activity, deviation, contact - mode of injury, and agents associated materials) within the study period;
- Collection of information regarding the nature and severity of the injuries and consequences of the accident (part of the injured body, type of injury and number of days lost) within the study period.

The reference period is defined between January 2013 and December 2014, and may in some cases be broader and/or shorter due to the data provided by the entities.

The sectoral scope refers to the activities of section and subsection F of the CAE Revision 3, namely in the Civil Construction and Public Works sector, which covers companies with a geographical location in the national territory (continental Portugal).

Thus, the questionnaire covered the sample selected, with the necessary guarantees of confidentiality of the data collected, with the intention of minimizing any deviation from the results.

The questionnaires were a research instrument consisting of a set of written questions, with objective knowledge of the views, interests and situations lived.

The questionnaires were applied through the personal interview method, guaranteeing the anonymity of the interviewees. Responses have been treated confidentially and will only present general results of the study, without any information that could lead to the specific identification of the participant.

3 Results and Discussion

A data collection was carried out, based on two questionnaires, carried out in a real context of execution of two works, that moved several sectors, upstream and downstream of its production chain. In both situations, the questionnaires were applied to a sample of 109 companies and 416 workers, in a total universe of 134 companies and 852 workers who participated in the entire production process.

All of the following data are the result of an investigation of a sample of 416 workers and 109 companies that participated in the entire production process, in the execution of two public works that have operated in various sectors upstream and downstream of their production chain during the period of analysis of this research study (2013–2014).

Regarding the number of hours of OSH training, it was verified that, except for occasional cases of technicians attending a TSST and/or recycling course in both years of study, the only contact with training in the area was given in sections on-site. On the ground, it can be seen that the workers of temporary work companies are more at risk. It is observed that about 94% of workers had up to 4 h of OSH training (Tables 1 and 2).

Table 1. Number of hours of OSH training (2013)

OSH training (h) year 2013	Frequency	Percentage
0	40	9.62
4	348	83.65
5	2	0.48
8	4	0.96
10	11	2.64
15	6	1.44
20	1	0.24
25	2	0.48
250	2	0.48
Total	416	100.00

Table 2. Number of hours of OSH training (2014)

OSH training (h) year 2013	Frequency	Percentage
0	3	0.72
3	1	0.24
4	381	91.59
5	3	0.72
8	5	1.20
10	12	2.88
15	7	1.68
20	1	0.24
25	3	0.72
Total	416	100.00

A natural and obvious situation results in the idea that all workers feel a need for more OSH training. In the field, they say that given the technological evolution, of materials and constructive solutions, it is essential to know the inherent risks, as well as the knowledge of preventive measures (Tables 3 and 4).

Table 3. Need for OSH training

Need more training in OSH	Frequency	Percentage
Yes	416	416
No	0	0
Total	416	416

Table 4. Value of the company's investment in OSH (2013–2014)

Company investment in safety and hygiene at work				
Value	Frequency 2013	Percentage	Frequency 2014	Percentage
[1; 100 000]	107	98.17	107	98.17
[100 001; 200 000]	2	1.83	2	1.83
Total	109	100	109	100

Despite the range of values mentioned in the survey, on the ground it is clear that investment in OSH, not only in training, but especially in local conditions, including collective protection, is small. Many workers have IPE's unused "*but they use it because they have it*".

In the analysis of the number of hours of training per worker, it is observed that around 4 to 5% of companies comply with the stipulated in the Labor Code [5]. They minister at least 35 h per worker (Table 5).

Table 5. Hours of training given by the company per worker (2013–2014)

Training/worker (h) in OSH		
Value	Frequency 2013	Frequency 2014
[1; 20]	104	105
[21; 40]	5	4

As a result of the statistical treatment, the following data were verified:

- The intermediate classes have the most training, namely 30 to 34 years and 40 to 44 years. It is also verified that the classes with more than 50 years are the ones that present less frequency of formation in OSH which, related to the one mentioned in the previous point, can indicate that the collaborators with less formation in OSH could be more exposed to the occurrence of accidents.

- If we associate ‘Time of Professional Experience in the Construction Sector’ and ‘OSH training’, it is verified that there is a greater discrepancy of employees with and without training in the older classes. This means that although there is still a marked shortage of OSH training for all employees, there is a considerable difference in the older classes between those who did not have training and those who did.
- After analyzing the intersection between ‘Company investment value in OSH’ and ‘Sinistrality Indices’, it is verified that the ‘Sinistrality Indices’ is lower where there is a higher value of the company’s investment in OSH.

4 Conclusion

It was found that instruments for an overall policy on occupational safety and health were designed to meet the need to promote the approximation of european standards on accidents at work and occupational diseases and also to achieve the overall objective of constant reduction and consolidated labor accident rates, also contributing to a progressive and continuous improvement of health and well-being levels at work [4].

To achieve these objectives, it is essential to introduce a culture of prevention, to facilitate the consultation and active participation of workers in the process of improving work organization, to adopt measures aimed at improving well-being at work, with a view to adapting work to man and their compatibility with family life, introduce factors of control and development of workers’ physical and mental health and promote health surveillance.

The study shows that the vast majority of workers do not have training in OSH. They only have in many cases only the training of reception on the job.

From the data collected in the surveys, it should be noted that the total number of workers in the sample who reported OSH training provided was insufficient.

Thus, there is no training that allows, for example, to make a correct disclosure of hazard identification and risk assessment, as well as the technical procedures and instructions for their control (defined as regards general OSH, and nowadays increasingly hands companies with SGSST implemented), the probability of failure due to lack of knowledge is greatly increased.

As shown by the data, there is a higher prevalence of OSH training in employees with less seniority, and is even more important, in the technical staff. However, when inserted in work environments where the majority of employees have performed the tasks for a longer time, but only based on their common sense and the experience of the function, employees with less seniority end up also adopting as their work practices the Who look at those who have been in the role for some time [1].

For the treatment of data, it is verified that the employees who have been in the position for more years have fewer literary qualifications and less training in OSH and, consequently, a greater number of occupational accidents. This reflects, according to the individual factors referred to by the HSE (1999), the importance that the school qualifications and levels of acquired competences possess with respect to the labor accidents [2].

One of the relevant situations, verified on the ground, is related to temporary work agencies. The precariousness, lack of information/training, often associated with the "subjections" that workers are exposed to, are a motive for reversing the recorded trends of declines in non-mortal and mortal labor accidents.

The most relevant explanatory variable in the explanation of the accident rates (Incidence and Severity) is the unemployment rate. Viewed in isolation from each other, but together with the variable unemployment rate, the variables participation rate in training actions and training costs per worker are also important, as evidenced by statistical reliability. Interestingly, these two variables act in the opposite direction, that is, an increase in the participation rate in training actions leads to an increase in the two accident rates, and an increase in training costs per worker leads to an increase in Index of severity.

These facts do not mean that the investment in Prevention and OSH should not be done. What it translates is that, as it is done, not only does it not lead to expected results, but even leads them to the opposite direction, to what would be intended. Companies (and the State) should rethink the type of training given to their workers and realize that the exponential increase in spending in recent years has not led to remarkable results.

In economic terms, over the period 2013–2014, what the average company spends per year in Prevention and OSH is more than what it saves with the possible decrease in work accidents, which only reinforces the conclusion of inefficiency of investment in Prevention and OSH.

It is verified that until 2013 there was a reduction of the average hours of training per participant, being the end of that year of 32.8 h.

Due to the results obtained, it is urgently necessary to place a question: what is so poor about the Prevention and Security in the Construction sector, in the face of such huge investments, which are often called for by successive Legislation in order to make it more demanding?

The easiest, and most dangerous, conclusion (because it becomes demagogic and reductive) would be: investment in Prevention and OSH does not pay off. This conclusion would not go to the root of the causes, nor would it even throw clues. And as the purpose of any research work, when, when answering certain questions, others arise, it will be necessary to try to outline new hypotheses of investigation and not to draw conclusions early. Because a more serious hypothesis is to say that investment, as it is done at the moment, is not compensatory. That is, it is not concerned what is spent on Prevention and OSH, but how it is spent or declared to be spent.

These results are highly worrisome and once again allow us to strongly question the objectives and quality of the training provided in companies, as well as the legal model that is defined in this area. It is once again proven that training is not enough, but the most fundamental is its adequacy to the reality of each company, with the risk here proven of the complete lack of return on investment made under these conditions.

It is also important to emphasize that, at the level of the training evaluation, it would be important to have an assessment that would allow the identification of the learning transfers effectively obtained, both for the individual and for the organization [4].

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Towards a Framework for Steering Safety Performance: A Review of the Literature on Leading Indicators

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Abstract. While remarkable progress has been made recently to improve the state of occupational safety, the number of occupational accidents is still unacceptable. In addition, the organizational costs related to these safety problems in the workplace are staggering. Therefore, effective strategies are needed to guide the continuous improvement of safety performance. Common approaches include setting safety goals, identifying the key activities/interventions to reach those goals, and evaluating performance. The most challenging and fundamental issue within these approaches is evaluating safety performance. While it has been a focus of safety professionals, concerns still exist among researchers with regard to how safety performance can be appropriately and accurately measured to improve decision support systems. Recently, researchers in the field of safety have begun directing efforts towards new approaches for measuring safety performance by addressing leading indicators. However, because of its nature and utility, the ideas and concepts of leading indicators have remained unclear. In an effort to overcome this challenge, this study attempts to distinguish between the two common aspects of safety performance, observable activities and outcomes. The importance of using leading indicators for steering safety performance is then highlighted. In order to meet these objectives, the results chain model, which has been introduced by several researchers for outlining the program development, is employed. The elements of the results chain model are then interrelated with relevant safety concepts. As a result, the relationship between the leading and lagging indicators and safety performance is identified. A set of leading indicators that predict safety performance is proposed. Further, the important implications of this study for both academic communities and practitioners are discussed as well.

Keywords: Safety performance · Leading indicators · Results chain model · Literature review

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1 Introduction

The vision stated by the National Institute for Occupational Safety and Health (NIOSH) highlights the importance of healthier and safer workers' role in promoting productivity in the workplace [1]. This vision is addressed in literature where several researchers discuss the advantages of safer and healthier workplaces including more productive workforce, improved financial performance, and lower healthcare costs [2, 3]. In contrast to the advantages of following Occupational Health and Safety (OHS) principles, significant problems can occur as a result of ignoring those rules. For example, nearly 6,000 deaths and approximately four million work-related injuries and illnesses are reported each year in the United States [4]. These problems affect both the employers and employees. While the organizational cost relative to poor safety at work is incurring, employees' families are also indirectly suffering from overlooking OHS principles in the workplace. Annual costs of more than $53 billion for workers' compensation have been reported by the United States Department of Labor [5]. Therefore, addressing OHS concerns can be a significant step in a companies' attempt to affect not only the companies' performance but also society.

Further, due to rapid changes in technology, new hazards have been brought in to the workplace. Subsequently, safety professionals should modify approaches to measure safety performance more appropriately; even though remarkable progress has been made to improve the state of occupational safety in the workplaces compared to the past. For instance, the number of deaths in 1912 (21,000) dropped to 5,000 in 2014 [4]. Despite this striking progress, there is still a need for establishing new strategies to control and reduce workplace risks. As an example, NIOSH recently launched the Total Worker Health (TWH) program to sustain and improve workers' health and safety in the workplace. Creating a safer and healthier workplace through establishing policies and programs is beneficial for individuals, families, and employers and their organizations, which further leads to productive communities. Although considerable studies have been conducted on the various aspects of safety and health in the workplace, less attention has been devoted to proposing a method for planning, predicting, and measuring OHS performance in an integrated and systematic way. For instance, how the antecedents of safety performance are related to safety activities and their final outcomes is still controversial among scholars [4]. A comprehensive conceptual framework for illustrating the possible relationships among safety concepts is clearly needed.

Further, considering preventive activities in safety can result in high return on investment. As an illustration, the American Society of Safety Engineers shows that companies which spend $1 on preventive activities in connection with workplace safety can lead to at least $3 saved. According to this fact, again, the importance of planning and predicting OHS performance is shown. Luckily, nowadays, safety programs have been directed to upstream safety efforts compared to the downstream approach in the past. Nevertheless, illustrating both upstream and downstream safety concepts in a conceptual framework is lacking.

The present study attempts to clearly and systematically illustrate the relationships among safety concepts in a comprehensive framework. To this end, a review of the literature addressing OHS indicators has been performed. Future studies can benefit from the proposed framework to develop specific and more consistent methods for measuring OHS performance in different operational contexts and according to different priorities.

The rest of the paper includes the different approaches of safety performance measurement in the next section, then, the introduction of the results chain model is provided, next, the linkage of safety concepts to the result chain model's elements will be provided. After that, Sect. 5 shows the upstream safety's concepts involving leading indicators and, lastly, implications of the study and conclusions are presented.

2 Measurement of Safety Performance

The foundation of a business management process includes measuring and controlling the performance. The gap between an acceptable level and current level of performance is identified by measurement [6]. Safety professionals are expected to establish similar approaches for managing safety activities and identifying appropriate interventions to create a safer workplace. In order to continuously improve the safety performance of a workplace, certain strategies are commonly employed such as goal setting, identification of the key activities/interventions to reach those goals, and performance evaluation. The most challenging and fundamental issue among these strategies is the evaluation of safety performance. Two common views exist regarding safety performance. The old view refers to blaming individuals for human errors and at-risk behaviors. By addressing this view, only humans were typically identified as the causes of accidents and injuries. As a result, the underlying indicators for measuring the safety performance within the old view included the number of accidents and injuries. Human error does not address the influencing elements behind an individual's activities or decisions. Therefore, the reasons, or root causes, that led to accidents and injuries remained unclear. After two catastrophic accidents, Chernobyl and Bhopal, researchers were warned that other elements also attributed to accidents in the workplace [7]. This limited view is not appropriate today; therefore, a new view is required.

The new view believes that human error is a symptom and not a direct cause of accidents. It focuses on root causes of accidents such as organizational factors, task characteristics, and working environment. Compared to the traditional approach, which failed to point out the direct factors influencing accidents and injuries in the workplace, the current holistic view provides a strong rationale for recognizing and controlling the causes of accidents. This approach can help organizations prevent accidents from reoccurring. Different tools and techniques to measure safety performance have been developed using the new view compared to the traditional approaches. The common indicators, which are used to measure safety performance, are known as leading indicators. These indicators address the underlying elements that had been overlooked under the auspices of human errors. For example, researchers have recently addressed the elements of safety culture, management commitment, personality, and work design as they relate to accidents and injuries in the workplace [8, 9]. Although new methods of measuring safety performance have been introduced by researchers, clear definitions of these concepts still require additional research. Further, experimental studies are needed to test and verify the advent of new concepts within the occupational safety context.

3 Result Chain Model

As previously mentioned, new tools and techniques have been developed with respect to safety performance measurement under the new view. To further the new view, clear definitions of safety-related terms should also be developed. This is the main objective of the present study. This research attempts to introduce the results chain model and its application to illustrate these safety terms more effectively.

In order to evaluate the impact of a program, the theory of change was developed by policy makers [10]. The simplest and clearest model to outline the theory of change is the results chain model, which sets out a sequence of inputs, activities, and outputs to illustrate how various elements lead to the final outcomes of a program [10]. The benefits of using this model are its ability to illustrate the theory of change, measure effectiveness, and develop a framework for cross-site learning. The results chain model provides a framework for analyzing the short-, medium-, and long-term results of a program. Figure 1 illustrates the structure of this model and the five underlying components, which include inputs, activities, outputs, outcomes, and final outcomes. The results chain model is employed in four main situations. First, it helps to signify assumptions about how various strategies can lead to desired results. Second, it provides a framework for designing a monitoring plan. Next, through the monitoring plan it is possible to analyze and adapt the plan according to the defined goals and organizational demands. Finally, the results chain model can be used for external evaluations.

Fig. 1. The results chain model [10]

Descriptions of the elements within the results chain model are as follows:

Inputs: Resources at the disposal of the program.
Activities: Actions taken to convert inputs into outputs.
Outputs: Tangible results produced by activities.
Outcomes: Changes (usually short to medium time range) resulting from activities and outputs.
Final outcomes: Final goal(s) of a program (typically achieved over a longer period of time).

This model has been used in diverse contexts. For instance, the World Health Organization (WHO) stated that the results chain model is the main method they employ to assess their programs' performance [11]. In addition, researchers have utilized the results chain model to evaluate the holistic impact of a program or policy. For example, Jahanmehr et al. [12] proposed a conceptual framework using the results chain model to evaluate public health system performance in Iran. They changed the underlying components of the model and used input, process, output, and outcome as the main sections. In another study, Gertler et al. [10] provided an example of using the results chain model to evaluate the performance of a new educational approach. The components of the results chain model in their study included: inputs (human, financial, and other resources), activities (designing new curriculum and training teachers), outputs (textbook delivered to the classrooms and trained teachers), outcomes (improved student performance and textbook usage by teachers in the classrooms), and final outcomes (improved completion rates and higher earnings).

The result chain model is based on the objective of a study and can be employed in different contexts. In the next section, safety performance and how its underlying concepts can be interrelated within the results chain model is discussed.

4 Interrelating Safety Concepts and the Results Change Model

A holistic framework embodying all safety concepts can help safety professionals clearly set safety goals, define indicators, and evaluate safety performance more appropriately. Furthermore, the new view of safety performance measurement requires a precise definition of safety concepts including safety activities, leading indicators, and antecedents of safety performance. Therefore, this research attempts to integrate the safety concepts into the results chain model by addressing the following perspectives:

1. The importance of the antecedents of safety performance in achieving safety goals.
2. The role of safety activities in achieving safety goals.
3. The position of leading and lagging indicators among safety concepts.
4. The association between a near-miss and an accident.
5. The function of safety behaviors among safety concepts.

In order to present these perspectives, the blocks of the results chain model are employed. By using this model, a sequence of events is depicted to illustrate the relationship among safety concepts from the initial elements and antecedents of safety performance to the final elements, accidents, and injuries.

Based on the definition of an input within the model, which is in connection to the resources of the program, an antecedent is an input to safety efforts. This is supported by Wallace [4], who states, “The people, tools, tasks, and operating environment can all be treated as inputs or antecedents of safety” [p. 2]. Additional researchers also mention antecedents of safety performance as any direct or indirect items that influence safety performance [7, 13]. According to the safety literature, there are four common antecedents for safety performance, which include working environment, task characteristics, workforce characteristics, and organizational factors [13–16]. Subsequently, these four elements were utilized as inputs for the proposed model.

Activities within the results chain model are defined as any action taken on the inputs to produce an output(s). Therefore, safety activities are defined as any undertaken action(s) in connection with the antecedents of safety performance. A proper indication of safety performance in the workplace can be determined by the consistency between safety activities and safety goals. Since early efforts in safety programs are referred to as safety activities, analyzing and evaluating this element can highlight inconsistencies between safety activities and safety goals in an organization. Therefore, in order to measure the status of safety activities, OHS leading indicators have been introduced in the literature. In several studies, the term of activities indicators is used interchangeably with leading indicators [4, 17]. For example, safety activities extracted from literature include training, risk assessment, job safety analysis, accident investigation, written information about OHS procedures, personal protective equipment, budget for OHS, and involvement of workers in setting OHS policies [18–20].

The next element in the results chain model is the output(s), which is described as the tangible results produced by activities. For safety, outputs are consistent with the definition of safety behaviors. Safety behaviors are the observable activities that are generated by employees [4] therefore, they are classified into two categories, safety participation and safety compliance. Safety participation refers to the participation of employees in voluntary safety activities [21], such as participation in safety meetings to address safety concerns and improving OHS programs in the organization. Alternatively, safety compliance refers to following the OHS rules in the organization [22], such as using personal protective equipment and following OHS procedures. Therefore, safety behaviors are the outputs of activities that were undertaken on the antecedents of safety.

The next element in the results chain model is outcome(s), which are short-term or medium changes that are a result of outputs and activities. A near-miss is an unplanned incident with short-term results that does not result in an accident or injury [23]. Since this definition is consistent with the outcome's definition in the results chain model, near-miss is placed as the outcome in the proposed model. Further, a near-miss can be a transitional indicator between safety behaviors and accidents. While near-misses are defined as an outcome for safety efforts, they can also provide invaluable information for preventing future accidents. Near-misses are short-term results of safety programs despite the existing potential to become accidents or injuries since they can provide a significant alert for safety professionals. By investigating near-misses, root causes are identified and preventive action plans can be implemented.

The last element in the results chain model is the final outcome(s). This item addresses the final goals of a program. Accident and injury reduction is the final goal of safety efforts in an organization. Moreover, due to the long-term impact of accidents, injuries, and occupational disease for both the individual and organization compared to the near-misses, these can be placed in the model as final outcomes. It is worth noting that a clear distinction between accidents and injuries is provided by [4], "Traditionally, accidents and injuries have been lumped together, yet accidents can happen in which no injury occurs such as in an instance of damage to a piece of equipment" [p. 3]. Therefore, measuring these final outcomes through lagging indicators reveals the impact of safety interventions. This information is useful for management as it provides managers with details about the overall status of the safety and health programs in the organization. The final outcomes can also be used as benchmarking measures.

Based on these definitions, a results chain model with related safety concepts was developed. Figure 2 provides the proposed model for illustrating safety concepts.

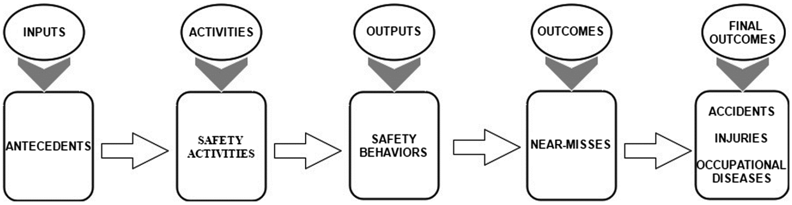

Fig. 2. Proposed model for safety concepts

5 OHS Leading Indicators

In this section, two additional definitions for leading and lagging indicators within the OHS context are described. Selecting the appropriate performance indicators is a critical step in safety and health program evaluation. After setting safety goals, the indicators are used to assess how consistent the activities and interventions are with safety goals. A clearly articulated framework for safety concepts provides a useful map for selecting the underlying OHS indicators along the results chain. In order to effectively monitor safety performance, two kinds of indicators are necessary: one indicator for monitoring the safety efforts and the other indicator for evaluating the results of safety efforts.

Table 1. Leading indicators linked to the antecedents of safety performance

Antecedents of safety performance	Leading indicators
Working environment	Assessment of working environment's hazards, correct tools and equipment, inspection of tools and equipment periodically, health facilities (e.g., toilet, showers), near-miss investigation, benchmarking, and audits
Workforce	Number of employees trained on OHS principles, OHS brochures/literature, verbal instructions on OHS, personal protective equipment, and training
Task	Job safety analyses, written information on OHS procedures, written information about safe working, and consideration of ergonomic factors
Organizational factors	Management commitment to OHS policies, safety culture, people's involvement in articulating OHS issues, OHS budget, OHS scheduling, reward system for correcting OHS issue, management walk throughs, and contractor management

According to this criterion, two types of OHS indicators already exist, which include leading and lagging indicators. Lagging indicators measure final outcomes of activities or events [24], and, therefore, are often referred to as after-the-fact indicators [25]. Lagging indicators were placed in the proposed model to measure the final outcomes such as accidents, injuries, and occupational diseases. Traditionally, recordable injury rate, days away, and restricted work have been introduced as lagging indicators, which are also consistent with the elements of the proposed model.

Leading indicators are known as the activities indicators, which help an organization take action(s) to lower risk(s) [24]. In addition, according to Step Change in Safety [26], leading indicators in safety are “something that provides information that helps the user respond to changing circumstances and take actions to achieve desired outcomes or avoid unwanted outcomes” [p. 3]. These statements are pertinent to the activities undertaken within safety programs. Therefore, the following definition for leading indicators is proposed: something that provides information about undertaken activities on the antecedents of safety performance. Table 1 provides the underlying leading indicators that were extracted from relevant safety literature [18–20, 23, 24, 27–30].

6 Implications of Findings and Conclusions

The proposed model has critical implications for both the academic community and practitioners. The sequence of safety concepts provides a holistic framework, which enables researchers and practitioners to understand the causal logic behind safety events. This framework can facilitate discussions on monitoring and evaluating safety efforts by showing what needs to be monitored and evaluated. Leading indicators can be used to monitor safety efforts and lagging indicators can be used to evaluate safety programs [24], as illustrated in the proposed model. Leading indicators measure the safety activities and lagging indicators measure the final outcomes. Moreover, measuring safety activities is a self-assessment of safety performance at lower levels of an organization as opposed to lagging indicators that are used at managerial levels. By conducting self-assessments, organizations can determine how consistent their safety activities are with their safety goals. Then, corrective action(s) can provide continuous improvement for safety efforts. On the other hand, through measuring final outcomes with lagging indicators, the overall evaluation of a safety program is possible, which enables management to make decisions regarding the organization’s OHS policy.

Measuring safety activities is effective for predicting future safety performance; however, predicting the outcomes itself is not necessarily possible. In other words, safety activities indicate only how effectively the safety programs are conducted. Additionally, measuring safety activities can be used to motivate and direct employees towards safe behaviors.

A combination of both leading and lagging indicators is recommended to determine appropriate safety program interventions. While leading indicators depict the safety-related activities and how well they meet safety goals, lagging indicators provide an indication of the efficiency of safety program interventions. The proposed framework integrates common safety concepts in a simple, comprehensive structure for future relevant studies.

Since safety has been defined as a process rather than an event [17], the entire safety process from the initial steps (inputs) to ending steps (final outcomes) must be considered. The proposed model maps the necessary steps to enable practitioners to monitor safety efforts by measuring safety activities and evaluating safety programs through the final outcomes.

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Applications in Safety Management and Loss Prevention

Motigravity: A New VR System to Increase Performance and Safety in Space Operations Simulation and Rehabilitation Medicine

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Abstract. Motigravity is a new immersive instrument developed by Mars Planet where one or more persons interact with a virtual environment using a visual and biomechanical system. The applications of this system are various; here, applications in space operations simulation and rehabilitation medicine, in particular, are presented. This paper aims to bring to the scientific community knowledge about this recently developed virtual reality technology in order to motivate cooperation, development, and application of this facility.

Keywords: Human factors · Human-systems integration · Virtual reality · Space mission · Medical rehabilitation

1 Introduction

In the last few decades, systems based on virtual reality (VR) have started to play a significant role in both research and industrial applications. These systems enable investigations in research areas related to medical, space, and human factors, and in the training of industrial operators. In the most recent years, they have also started to be used in the gaming, entertainment, and educational industry [1].

As far as space research applications are concerned, for long-duration crewed missions to Mars, human space mission simulators using VR play an important role in the development and testing of hardware and software technologies. Simulators also provide a viable platform for conducting research in space, e.g. in the areas of psychology, physiology, medicine, mission operations, human factors, and habitability.

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These research areas are critical for ensuring the well-being of the crew and enhancing performance in long-term space missions.

In this context, Mars Planet (former the Italian Mars Society) has developed a new VR facility for testing and developing space technologies and medical applications named Motigravity (Fig. 3). This facility allows:

- Immersive visual scenarios
- Reduction of weight to emulate varying degrees of surface acceleration
- Mobility/locomotion on a treadmill
- Real-time connection with other users in virtual reality
- Virtual interaction with immersive visual and audio environments using the Oculus Rift technology
- Tracking of user movements inside a 3D virtual environment and reproduction of these movements by an avatar.

2 Structure of Motigravity

Motigravity can be customized like a general VR-based tool included in all the ground system simulation architectures for which systems are foreseen both for the purpose of astronaut training and mission control operations. The basic structure of the device is composed of different parts:

- **Hypogravity lifting system**: A mechanical frame connected with a treadmill base and a user lifting system, which includes different kinds of lifting and harness systems consisting of both hardware and sensors to enable simulation of users' movement in low gravity, including walking or interacting with the environment.
- **Treadmill base**: A round, concave platform used to allow movement of the lower body part. In this project, it is also connected with virtual sensorial interaction of the upper part of the body.

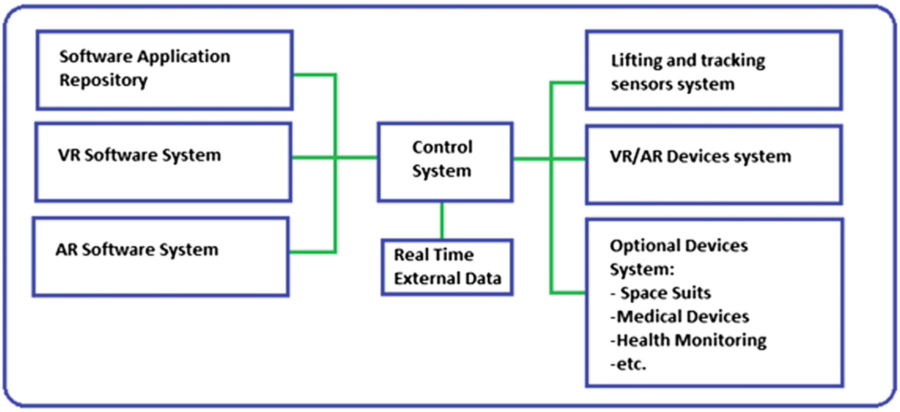

Fig. 1. Motigravity overall architecture

Fig. 2. Motigravity first prototype ((c) Del Mastro, 2015)

Fig. 3. Motigravity final version ((c) Del Mastro, 2017)

- **VR/AR software system:** A specific software control system including the VR/AR applications necessary for simulating the experience has been developed by Mars Planed ad hoc.
- **VR/AR devices system:** A system composed of both VR devices like Oculus rift and artificial reality (AR) systems like Hololens, which can be used alternatively to test the tool both in VR and AR environments.
- **Optional devices:** The system is adaptable to allow interaction with extra equipment such as space suits, medical devices, health monitoring systems, as well as a lower-body hypogravity simulator. This last device consists of a plastic bag cylinder into which pressurized air is injected and into which the lower part of the astronaut's body is inserted. This device helps to reduce the gravity experienced by the user and can also be used as a tool for rehabilitation exercises. The device is optional and can be added when needed.

The overall architecture of the Motigravity tool is coordinated by a central control system able to process the external data in real time (Fig. 1).

3 Example of a Tested Space Application

In particular, this VR system has been developed on the basis of the lessons learned from the use of previous versions (Fig. 2) in various tests and experimental applications such as a study on safety and training for Space applications [1, 2]. We describe one example of utilization of the Motigravity system in the framework of the AMADEE-15 Mars simulation [3]. During the simulation in August 2015, a set of pilot tests were conducted during a 12-day emulated operational Mars exploration simulation at the Kaunertal Glacier in Austria. Eleven experiments were conducted by a carefully selected and trained field crew at the test site, coordinated by a Mission Support Center in Innsbruck, Austria.

The research fields covered by the experiments encompassed geology, human factors, astrobiology, robotics, tele-science, exploration, and operations research. A Remote Science Support team analyzed the field data in near-real time, providing planning input for a flight control team to manage a complex system of field assets in a realistic workflow, including advanced Space suit simulators as well as robotic and aerial vehicles. A 10-minute satellite communication delay and other limitations pertinent to human planetary surface activities were introduced. A previous analysis of historical missions, like the EVAs during the Apollo lunar missions, revealed a significant deviation between planned versus actual traverses, leading to delays in the flight plan [4]. Hence, predictive tools can be a key factor for the success of the mission and in the case of Motigravity, this means that the tool can be used to allow better prediction capabilities [5]. In the course of the "Virtualization Experiment for Mars Expedition Simulations "(VEMES) pilot experiment, two Motivity stations (the treadmill developed by Italian Marsefore Motigravity) were deployed at the field test site at a glacier base station at 2700 m, while two simpler versions were set up at the Mission Support Center. By using the vertical treadmill with the gravity-offloading climbing harness together with the exoskeleton of the AOuda.X spacesuit simulator, the movements of the astronaut were recorded with a Microsoft Kinect, which translated the movements into a virtual world based upon a Blender software model. Head movements were measured via the head-mounted display. The physical test site was imaged from a 6-propeller drone carrying a digital camera. Point clouds and a 3D mesh were created from the images, and the textures subsequently applied to the mesh, resulting in a high-resolution 3D model.

Three males with a mean age of 30.3 ± 5.5 years participated in 11 virtual EVAs; all of them were fully trained and certified analog astronauts [5]. Their subjective assessment was based upon a structured questionnaire which allowed ratings from 1 (inadequate) to 5 (excellent), (Fig. 4). The representativeness of the virtual EVA vs. the actual physical one was rated as 4, its effectiveness for familiarizing oneself for future EVA was 5, although the adequacy for identifying hazardous areas was only 3.6, which was attributed to the resolution of the DEM [5].

Using digital elevation model data and high-resolution aerial photography, flight planners were able to virtually "pre-enact" the locomotion of the analog astronauts, which would then execute the actual traverses, qualitatively estimating the workload and effort needed for the respective extravehicular activities: Once the EVA traverses

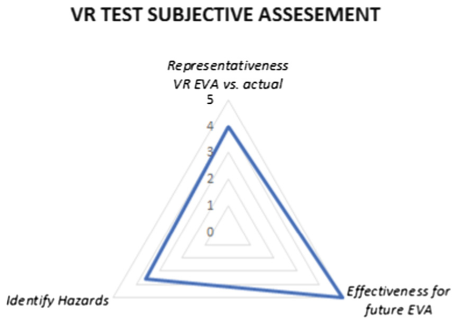

Fig. 4. Subjective assessment of the VR test with Motigravity

had been finalized by the flight plan teams, the Sat-DEM and photogrammetry terrains of the corresponding future EVA sites were used for IVR simulation of upcoming EVAs. Three OeWF analog astronauts participated in 11 virtual EVAs. They entered the Motigravity station and conducted their future EVA virtually, familiarizing themselves with the traverse path, obstacles, optimal routes, and mission-relevant landmarks.

As a result, the virtual reality system proved itself as a valuable training tool, although a sufficiently high terrain resolution is required to enable the identification of individual rocks for sampling and hazard avoidance (Fig. 5).

Fig. 5. Motigravity system (left) with elements of the Aouda.X spacesuit (right) to mimic the movement restrictions of the spacesuit ((c) OeWF/Paul Santek).

4 Example of a Planned Medical Application

The initial purpose of the Motigravity tool was to help astronauts handle their future habitat inside an appropriate simulation: Its general design allows weight reduction reproduction of different gravitational field effects on our mass. In association with a virtual environment, it becomes possible to make a powerful cognitive impact and enhance the learning process. But the possibility to reduce the weight safely by means of a virtual interaction highlighted several unexpected potential uses.

Virtual simulations of the real world are used in clinical studies: High realism and immersion appear to be useful in the treatment of neuropsychiatric diseases and behavioral troubles. This might concern almost 450 million patients all over the world. According to the World Health Organization, one out of four people has or will develop a mental disease during their lifetime [6, 7]. Thus, abnormal thinking and trouble with perception, cognitive impairment, lack of emotions, or behavioral diseases are some of the areas targeted by this cutting-edge treatment using serious games: The patient is in a virtual environment like in a habitat and evolves as he would in his daily life. The objective is to help him face his fears or behavioral problems in order to improve his real life [8–10]. For example, one scenario could be used to treat claustrophobia: The patient is taking an elevator. As a first step, he goes to the first floor within a few seconds. He repeats the scene until he is able to go up to the last floor of a building, maybe the 40th floor, with a stop at the 20th. Each scenario could be adapted to treat any problem. Moreover, various institutions are nowadays trying to find innovative solutions using virtual reality to treat Alzheimer's or Parkinson's disease or to improve stroke rehabilitation [11–14].

Associated with exercises, the general solution becomes interesting for both social and functional rehabilitation. Effectively, the Motigravity tool per se, as designed, might have an important impact for post-traumatic injuries or diseases with neuromuscular disturbances and degeneration [15, 16]: Placed at the center, the patient will be able to walk and to repeat the exercise with gradually increasing intensity. Treadmills are already in use in research to help treat children with cerebral palsy, which is a group of permanent movement disorders (coordination problems, stiff and weak muscles, tremors, etc.) that appear in early childhood; however, there is still some work to be done to improve the actual systems and results. Motigravity could bring an innovative solution with the use of virtual reality, where virtual objectives, motivation, and targeted exercises could be mixed in a ludic protocol [17, 18].

Indeed, this mechanism allows working on locomotion, postural rehabilitation, and equilibrium as well as on spatial navigation and other disorders through virtual reality [19, 20]. Besides Space training, this global use for public health could also become a routine in Space for astronauts' post-flight rehabilitation and fighting the aging effects of Space exposure. Spacemedex is currently working on the design of clinical studies and the transfer of this technology from the aerospace sector to the non-Space medical field. This will involve experts from institutes in neuropsychiatric disease, locomotion, and aging. The next step would be to integrate haptic control and the grabbing of virtual elements to simulate reality even better and achieve greater stimulation.

5 Comparison with Existing VR Treadmills

When Motigravity was designed, other forms of simulating hypogravity [21] and existing VR treadmills were also analyzed in order to better identify what could be the added value features of the tool (like the one from NASA Fig. 7). Differently to the comparison made between the tools for simulating hypogravity, the comparison of the Motigravity performance with general VR treadmills also helped to target the possible market for a more general application of the tool in sectors other than those described in this paper, such as gaming or educational applications.

Below, the main factors and the rates used to analyze the different products are listed:

1. **VR application**: scientific (Space, medical, rehabilitation, …), entertainment (gaming, sports, …), commercial (promotional, advertising), military, educational (training, academic), other.
2. **VR immersivity level**: defined here as the quality of being immersive, based on the level (0 not present, 1 basic or present, 2 advanced) of interaction involvement on different sensorial planes such as: motoric (not present, basic tracking e.g. partial body, advanced tracking e.g. complete body), auditive (not available, basic e.g. PC audio signal, advanced e.g. headphone or special audio software), visual (not available, basic e.g. computer monitor, advanced e.g. Oculus Rift), extra features (not present, present e.g. reduced weight system, hypogravity simulation)
3. **Hypogravity simulation**: no
4. **Harness system user friendly**: low (does not allow spontaneous and easy movements), medium (allows partly spontaneous and easy movements), high (completely allow spontaneous and easy movement)
5. **Quality of VR software**: real-time response and quality of rendered world and interaction with the VR environment: not present, basic, medium, advanced.

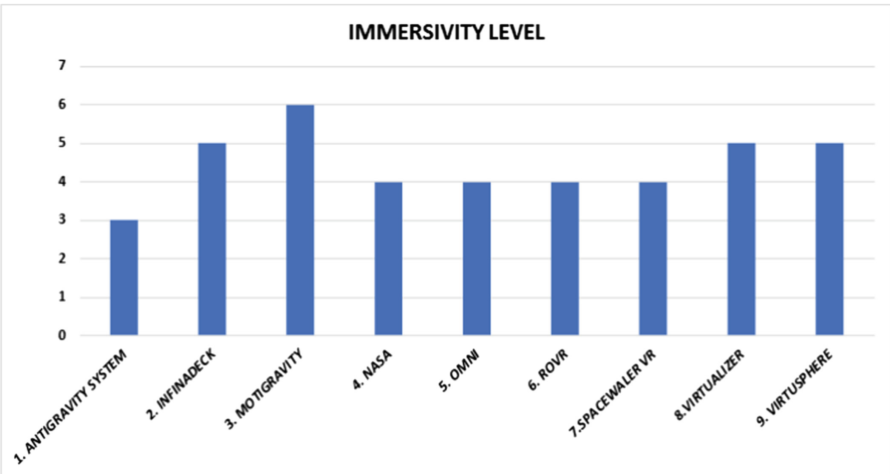

Fig. 6. Comparison of immersivity levels between different models

6. **Dimension**: the longest dimension between the diameter of the base or the height of the treadmill: big (>3 m), medium (<3 m and >1.5 m), small (<1.5 m).
7. **Price:** in $ or €: high (>50,000), medium (<5,000 and >800), low (<800), not available.

As shown by Fig. 6, we can observe that the majority of the models have a value of between 3 and 5, while Motigravity distinguishes itself by having an immersivity level of 6. Indeed, Motigravity has a strong competitive characteristic also, as it is one of the few instruments that allow experiencing hypogravity with relatively low dimensions and low costs. The further development of the tool is also expected to increase the value of its immersivity level parameter.

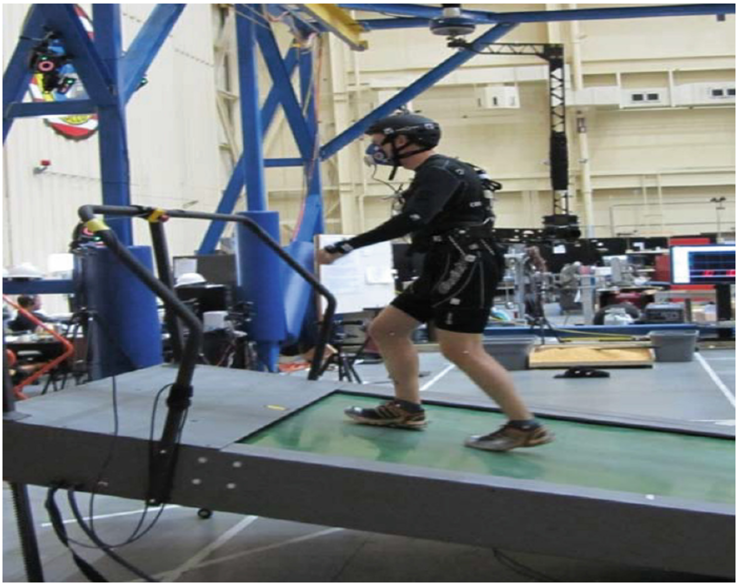

Fig. 7. Argos system by NASA ((c) NASA)

6 Test of Performance Quality

The performance of the Motigravity tool has been tested using different configurations in order to select the best combination of required memory, CPU, and graphic cards options, and VR visors such as OCULUS rift and HTC Vive. In particular, selected metrics already being used as parameters in many applications in the VR sector [22] have been applied to evaluate the quality of the performance of Motigravity. The list of foreseen metrics that has been used for the performance evaluation of Motigravity is reported in the following.

- **Timing accuracy:** [23] in terms of delay regarding real-time interaction. In particular for Motigravity, these parameters are essential to be evaluated in the case of

Space and medical simulations such as telemedicine, as the performance of the tool should really simulate the real-time behavior of astronauts and patients.

- **Position accuracy:** [23] This is intended as the spatial inconsistency between physical moves and visual feedback, which in the case of Motigravity is essential for the simulation of astronaut activities and medical studies.
- **Visual perception:** This is intended as the capability to identify the quality of the VR visual scenario. In Motigravity, the best distances between objects in the VR environment have been studied by creating ad-hoc VR test scenarios or changing the perception due to different frame rates.
- **Rendering:** In Motigravity, the rendering capability is optimized via appropriate ray tracing, shading models, optical distortions, and latency reduction algorithms of the VR software.
- **Manipulation:** This is the capacity of the user to interact with and change the environment. To improve the performance of the Motigravity tool during manipulation tasks, the choice has been to focus on some basic activity such as: selecting, grasping, manipulating, carrying, placing, also applying the "basin of attraction" principle: an object is truly identified/attracted/moved by the user when the user reaches a specified area ("basin").
- **Audio:** The audio performance in Motigravity is improved by means of appropriate sound filters and software both for the case of sound arriving in the virtual environment from external sources (signals from Space, commands received by patients during their rehabilitation exercises, etc.) and for sound generated in the virtual world and transmitted to the real world.

7 Conclusion and Further Development

Motigravity can be defined as an innovative VR tool for Space and Earth applications such as Mars mission training, as well as for rehabilitation and telemedicine. In particular, it is characterized by the possibility to simulate hypogravity as well as the high level of immersivity, low dimensions, and low costs. This paper has presented some of these features in order to motivate further development and cooperation in the VR/AR field.

With regard to planned further development applications of the tool, also based on previous experience like AMADEE-15, the simultaneous use of Motigravity in different locations on Earth is envisioned to investigate the performance of tasks by astronauts or subjects located in regions with either extreme or standard environmental conditions like Space and medicine laboratories. This application is a special case of the overall Mars City project carried out by the Mars Planet organization, which also includes the reconstruction in VR/AR of entire regions of Mars (V-MARS program). Under evaluation is also a comparison of the performance using Motigravity and the experiences made by astronauts during low-gravity flights. In this context, an analysis is also ongoing regarding what kind of metrics to set up for an appropriate comparison between the two simulation techniques.

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Two-Hand Actuator Placement for Power Press Operation: A Reexamination of After-Reach Speeds

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Abstract. This study reexamined data from an earlier study by the U.S. National Institute for Occupational Safety and Health addressing the after-reach speed of press operators—a speed that is a key part of standards for locating two-hand actuator buttons from the point of operation. The 60 participating press operators performed four reaches in each of two button placements. The investigators reported on the fastest of the four for each operator. They concluded that the 1.6 m/s value is inadequate to protect many of the faster press operators. For this paper, all reach speeds were analyzed and used to identify the percentiles of all after-reaches that were slower than several common percentile.

Keywords: After-reach speed · Safe distance · Machine safeguarding · Power press

1 Introduction

Among the many sources of industrial injures, one is amputations involving operation of mechanical power presses. Two investigations illustrate the magnitude of this problem. First, a paper based on U.S. workers' compensation records estimated over ten thousand amputation per year involving presses [1]. Second, reports of occupational amputations submitted to the U.S. Occupational Safety and Health Administration contained 2184 cases; 29% were from presses using two-hand actuators [2].

The use of two-hand actuators on presses is widespread. Suokas reported results of a survey about mechanical power presses in Finland that found that over 60% used a two-hand actuation method for actuating the stroke [3]. To set up these kinds of press operations, the two-hand actuator buttons need to be far enough from the point-of-operation to protect an operator who may initiate the downstroke by pressing both buttons, then suddenly reaching with one hand to adjust a mis-positioned part [4].

A formula for achieving this protection is widely used throughout the world. The formula is used to compute a "safe distance" between the buttons and the point-of-operation. The formula computes this "safe distance" by multiplying the time is takes to remove the hazard of a descending ram by a "hand speed constant" [4]. According to a review of studies looking for a value to use for the hand speed constant [5], the commonly used value of 1.6 m/s originated during the 1930 based on a small study of reach speeds achieved by students participating in the study.

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The U.S. National Institute for Occupational Safety and Health (NIOSH) revisited this “hand speed constant” by constructing a press simulator to use for further studies [6]. The largest and most representative of their studies was conducted by NIOSH investigator Timothy Pizatella [7]. He obtained cooperation of 60 machine operators working in two large machine shop. Most of them worked on mechanical presses as a major or minor part of their work. The results demonstrated that many of the participants could achieve hand speeds faster than 1.6 m/s [7]. From this finding, the logical conclusion is that the hand speed constant in the “safe distance” formula should be increased to some value greater than 1.6 m/s. The authors of the NIOSH paper concluded that to protect all operators, the value would need to be 3.0 m/s. If this were to be adopted, the “safe distance” would become so large it would require press operators to lean their upper body forward to reach the die on every cycle, and some with shorter arms would not be able to reach at all. Dellman studied press operations from an ergonomics perspective, resulting in recommendations to avoid setups that require the operator to lean forward on every cycle [8]. Because this apparent conflict among practical set up distances, ergonomics, and operator protection seems unresolvable, this study was undertaken to explore the NIOSH data in a different manner.

As described in earlier papers [4, 7], the NIOSH study examined two palm-button placements, an upper one about shoulder level, and a lower one about waist level. Measured from the floor, these were at 106 cm and 84 cm, respectively. Figure 1 illustrates these two placements and the direction of pushing the buttons. In each placement, the participating operator followed a protocol resulting in four after reaches. For each placement, the NIOSH investigators took the fastest of the four reaches by each operator. This resulted in a data set containing 60 out of the 240 after-reach times for each placement.

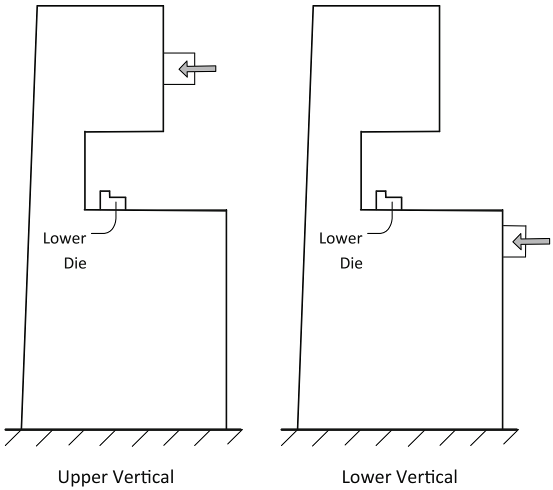


Fig. 1. Illustration of the two palm-button positions used in the NIOSH study [7].

For the present study, a different approach was taken. Instead of taking each operator's fastest of four after-reach motions, this analysis explored the inclusion of all four. By approaching the data this way, after-reach speed distributions may be developed—allowing identification of speeds for which particular percentiles of all 240 after-reach movements were slower. The end-point of this investigation is to provide information that will be available for consideration by standard-setting organizations concerned about the safe operation of mechanical power presses and other machines operated by two-hand actuation.

2 Methods

2.1 Data Source

After-reach data used for this analysis came from the NIOSH study of 60 machine operators. Each operator performed four after reach motions in a lower-level placement, and four in an upper placement. Using the NIOSH data, the approach reported for this paper was to include all of the 240 after-reach speed measurements in each placement.

2.2 Data Analysis

The initial analysis used two data sets—one for the upper placement, and one for the lower placement. Values were mean speeds for each of the 60 subjects. Plots clearly showed each distribution was other than normal; both being skewed to the right. In order to identify points in the distribution corresponding to percentiles, each subject-specific mean speed was transformed by its $\log_{10}$. Histograms and normal probability plots for the transformed datasets were generated for examination visually and statistically.

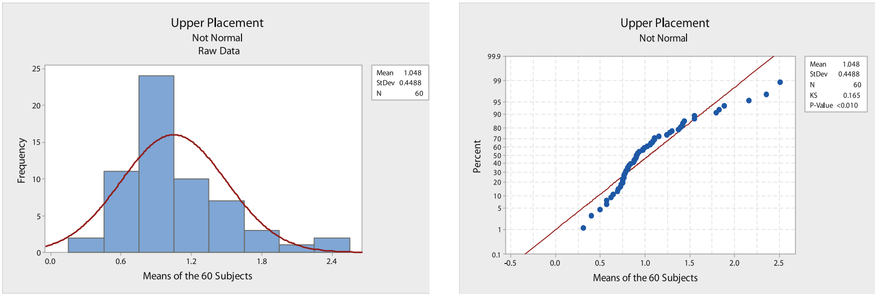
For each placement, all 240 after-reach speeds were combined in a data set and transformed to their $\log_{10}$ values. Using the mean and standard deviation of each data set, speed values were identified corresponding to common percentiles levels (2, 5, 10 25, 50, 75, 90, 95, 98, and 100). For each percentile point of the transformed data, the original after-reach speed values were identified.

3 Results

The initial aim of this statistical analyses was to establish data sets that fit a normal distribution. The steps described in the following subsections involved: (1) checking the raw speed data for normality, (2) finding a transformation that that provides a normal distribution, and (3) identifying after-reach speeds corresponding to percentiles of the after-reaches.

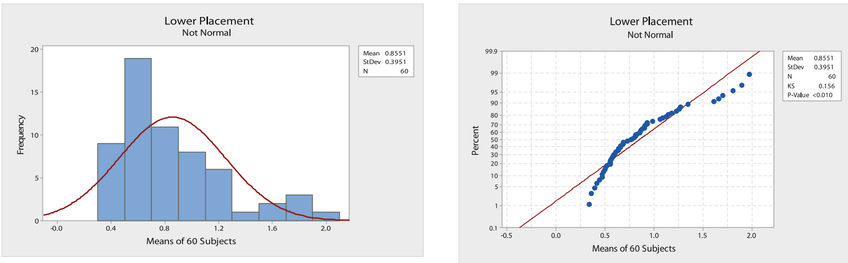
3.1 Checking Raw Data for Normality

The subject-specific mean speeds (S) were organized into two data sets. These were initially examined for normality using Minitab 17 software. For each set of mean speed data, the null hypothesis of normality was rejected ($p < .01$). Figure 2 contains graphs for the upper placement mean after-reach speeds. Figure 3 has the same types of graphs for the lower placements.



Histogram with Normal Curve   Normal Probability Plot

Fig. 2. Upper placement mean speeds in m/s for 60 subjects; not normally distributed.



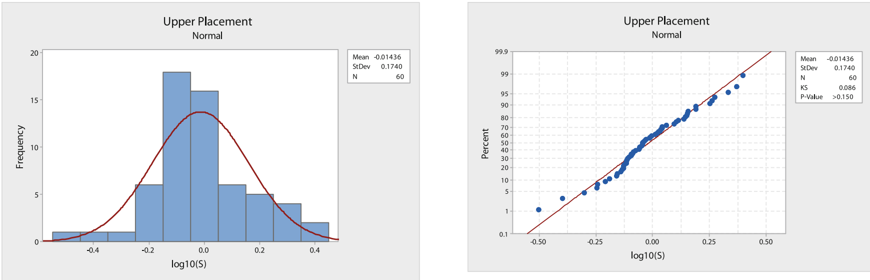
Histogram with Normal Curve   Normal Probability Plot

Fig. 3. Lower placement mean speeds in m/s for 60 subjects; not normally distributed.

3.2 Transformation to Create a Normally Distributed Data Set

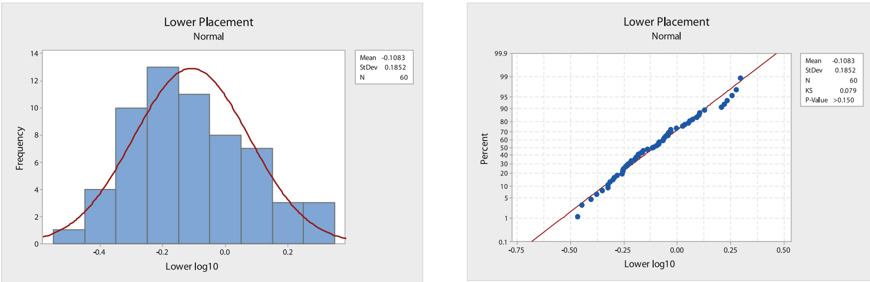
These subject-specific mean speeds were transformed using the function $\log_{10}$ S. The two transformed datasets for upper and lower placements were tested for normality by visually examining histograms and running a Kolmogorov-Smirnov (KS) test. The null hypothesis was that the dataset is normally distributed.

Graphs of the upper-placement and lower-placement transformed data are displayed in Figs. 4 and 5, respectively. Also shown to the right of the plot are results of the statistical comparison. Both KS values were greater than the traditional 0.05 rejection level (each $p > 0.15$); therefore, the null hypothesis of normality was not rejected. Thus, subsequent analyses were based on the belief that each set of transformed data consisted of normally distributed values of $\log_{10}$ S.



Histogram with Normal Curve Normal Probability Plot

Fig. 4. Upper placement, transformed data distribution; normally distributed.



Histogram with Normal Curve Normal Probability Plot

Fig. 5. Lower placement transformed data distribution; normally distributed.

3.3 After-Reach Speeds by Percentiles

Using the mean and standard deviation of the transformed data sets (each with 240 speed values), points were identified for various percentiles of values below the points. For each percentile point of the transformed data, the corresponding after-reach speed values (m/s) were identified. Table 1 contains the percentile values and the corresponding after-reach speed for the two placements.

An example of how the Table 1 data should be interpreted is illustrated using the 95 percentile value. Out of all after-reach motions made by press operators, 95% will be safe if the hand speed constant were to be 2.142 m/s for the upper placement, and 1.877 m/s for the lower placement.

Table 1. Percentile values and corresponding after-reach speeds

Percentile	After-reach speed (m/s)	
	Upper	Lower
2	0.297	0.200
5	0.387	0.272
10	0.460	0.340
25	0.632	0.480
50	0.914	0.719
75	1.302	1.066
90	1.677	1.523
95	2.142	1.877
98	2.643	2.401
100	3.160	3.626

4 Discussion and Conclusions

If standard-setting bodies decide to reconsider the after-reach speed value, they should appreciate two different approaches for choosing a speed constant in relation to percentage protected. The first is to seek a speed to protect the operators with the fastest speeds. That is the traditional approach used for occupational exposures to health hazards. The second is to seek a speed to protect a specified percentage of after-reaches that may occur among press operators. That is what this study explored.

One rationale for considering this alternative approach is our lack of knowledge of how frequently after-reach motions are made. Machine operators using a press with two-hand actuation may do so with frequencies ranging from infrequent to full time. Second, we do not know how frequently operators make an after-reach motion. For example, out of 100,000 cycles, how many after-reach movements can we expect, and of these, how many result in an operator reaching all the way to the point-of operation?

Another part of this rationale stems from the way occupational safety standards are developed. An example from the United States may serve to illustrate this point. In the process of making a fall protection standard, the consensus is that employers should only be required to provide fall protection when one of their employees is exposed to a fall greater than X feet. Various standards organizations have adopted different distances, e.g., 15, 10, 6, and 4 feet. Regardless of which height is adopted, some people who fall less than that distance will sustain a seriously injured, and some will die. Knowing this, the standard setting organizations have attempted to incorporate a fall distance that involves a compromise between protection and practicabililty. A relatively conservative standard like 4 foot will protect a large percentage of those who fall, but not 100%, and probably not even 90%. The point is that when occupational safety standards are developed, practicability plays a more significant role that when occupational health standards are developed.

In conclusion, this paper describes objective information on the distribution of after-reach speeds based on tests of 60 machine operators working in two American machine shops. It identifies the after-reach speeds that were less than particular percentiles, and offers that information for consideration by standards making organizations.

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Risk Communication for Consumer Products

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Abstract. There are many ways that product manufacturers can communicate risk to consumers. The hazard control hierarchy describes the fundamental elements and appropriate methodology for implementation of research-supported concepts and provides effective techniques for risk communication. Distinctions among types of risk communication and relevant standards are reviewed. Comprehension of risk information by product users is an essential part of the communication process. Label conspicuity and placement on the product are considered as to how they impact the efficacy of a warning, and are evaluated in real-world applications. Anti-warnings: communications that downplay risks and/or undermine warnings are also important to consider and are discussed relative to their effect on warning communications.

Keywords: Risk · Hazard control hierarchy · Safety symbol · Pictorials · Warnings · Anti-warnings · Human factors

1 Introduction

There are several ways that product manufacturers can address risk to consumers, including the hazard control hierarchy, techniques for risk communication, relevant standards and label conspicuity.

2 The Hazard Control Hierarchy

The hierarchy of risk, also referred to as the safety hierarchy or hazard control hierarchy, is typically defined by three fundamental elements: design, guarding, and warning [1, 2]. Design refers to the primary step in risk identification and management, in which potential hazards are designed out or effectively removed from the product. The second level, guarding or barriers, separates users from the hazards. Warning, or risk communication, represents the third level of the hierarchy and is used when neither of the first two approaches is feasible or while changes are in process. While a properly designed warning communicates sufficient information to allow individuals to make informed

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decisions on product use, this remains the least preferred method due to the difficulty in reliably influencing behavior.

2.1 Basic Fundamental Elements

As depicted in Fig. 1, the base of the hierarchy is the product design itself; the second level is to guard, and the final level, warn, is the least effective. The elements are prioritized from the base to the apex.

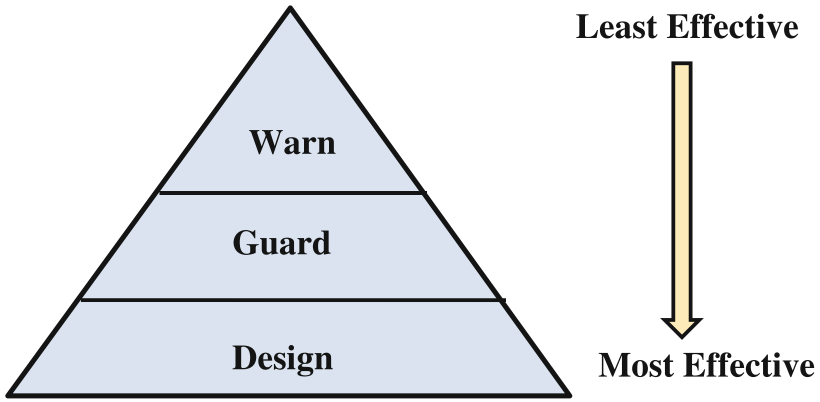

Fig. 1. The hazard control hierarchy is typically defined by three fundamental elements: design, guard, and warn.

Design. Manufacturers have the responsibility to remove known risks from products to the extent possible. The concept of risk applies not only to dangers that are present due to design characteristics or flaws, but also those indicated by potential design failures due to foreseeable misuses [2]. After a product or process has been fully designed, it must be reviewed with the specific intent of identifying safety risks by testing it with the foreseeable user population. For optimal safety results, a design will be revised as necessary, addressing each identified risk, until all are reduced or eliminated to the extent possible. Risks eliminated in the design phase of implementation will not be presented to consumers, and thus will not contribute to the potential of accident or injury [2]. Unfortunately, such resolution is often not possible, because modifications will countervail the purpose and use of the product or because the mitigation of one risk will disproportionately increase or unintentionally create another risk.

Barrier/Guard. When not all identified risks can be adequately reduced or eliminated through design, those that remain are addressed by guarding: a barrier that physically prevents users from exposing themselves to product risk [2]. An example of a barrier is a guard covering the blade of a table saw. For less tangible products, barriers are somewhat harder to describe but are no less present. Computers regularly come with preloaded antiviral programs and firewalls, presenting an intangible barrier to certain risks inherent with an internet connection.

Warn. Warning is the final and least optimal stage of the fundamental risk hierarchy. When neither design changes nor barriers are feasible or effective, a warning is used [2]. Warnings are the least effective strategy of the three fundamental levels of the hierarchy because they are designed to inform rather than limit a consumer [2] (see Sect. 3.2).

2.2 Elements May Be Added in Certain Use Environments

There are additional hierarchy elements appropriate for inclusion in certain environments, such as the provision for personal protective equipment (PPE), safety policies/procedures, and training. Risk hierarchies for workplace *policies and procedures* (in addition to product warnings and instructions) can be considered separately from those developed for products, due to the inherent differences. *Training* of policy and procedural design, defined for the purposes of this section as the establishment of proper usage protocol recommended to workers, can be adjusted at any point in time, including after being introduced to the workplace.

2.3 Adoption of Hazard Control Hierarchy

Users cannot benefit from risk reduction unless an appropriate hierarchical design is both adopted and implemented. Even successful implementation will not eliminate 100% of risks presented to consumers: the goal of a risk hierarchy is to lower the risk levels to the lowest practicable level, or ALARP (as low as reasonably practicable) in UK Health and Safety legislature [3]. Similar standards can be referred to under a number of names, such as ALARA (as low as reasonably achievable) common to the US [4], the ‘essential requirements’ set forth by the EU-OSHA [5], or the more general concept of ‘good engineering practices.’

3 Methods to Communicate Risk

There are different ways to communicate risk. Primarily, instructions and warnings will be defined and differentiated; the former not requiring the consistent formatting seen in a recognized warning.

3.1 Instructions

Instructions are designed to inform consumers of the proper and intended uses of a product in order to minimize exposure to risk and are included with nearly every product, whether it be a toy, a vat of industrial chemical, or an assembly-required chair. The American National Standards Institute (ANSI) categorizes instructions and manuals as ‘collateral materials,’ which often contain multiple pages of integrated, non-safety information alongside multiple longer and more detailed safety messages, which would not be practical to communicate on a label or sign. The ANSI Z535.6 under the title ‘Product Safety Information in Product Manuals, Instructions, and Other Collateral Material’ defines standards for proper colors, symbols, and information required in risk communication in such materials [6]. These are paralleled by international standards such as IEC 82097-1 and ISO 3864, used respectively for establishing regulation of instructions and graphical symbols [7].

3.2 Warnings

Warnings are used to address a variety of risks: when using a product, performing a task, or encountering a specific environment [2].

Development. In order to effectively communicate risk, it is important to test warnings and symbols with foreseeable users to verify that they are understood [8]. This is an iterative process, which requires constant updating throughout a product's development and release. Initial development of a warning communication system must be done during the product development to address risks that cannot be reduced to acceptable levels with a warning. Risk communications should be comprehensive, relevant, and evaluated for comprehension. Warning development requires identifying all foreseeable user populations, identifying potential confounding factors – such as native language and education level – which may negate the efficacy of a communication, and developing warnings that will be understood by relevant populations.

After a product is placed in an open market, active monitoring and evaluation must be maintained, both for the identification of unforeseen or unidentified risks which were missed during earlier developmental phases and for failures in risk communication and product labeling (on product, packaging, manuals, advertising, website). After exposure to the general public, issues such as incomprehensible language, unclear use of symbols, or inconspicuous placement of warning labels should be evaluated based on incident occurrence. If such failures are identified, or if newer adaptions of a product are to be released, risk communications must be updated accordingly to remain effective [9].

Warning Design. The design of a risk communication associated with consumer products is intrinsically related to the final efficacy in terms of consumer safety. If a warning design is suboptimal, communication of potential risks associated with a product can be undermined in a myriad of ways so manufacturers are obligated to consider many factors relating to the product and consumers, which will affect the final warning design.

The medium of a risk communication is of primary consideration – while visual risk communications are the most common, consumers may also be presented with risks in auditory and olfactory formats, addressed below. Both the product being marketed and the population it is marketed to must be evaluated to determine the most appropriate medium for risk communication.

If consumers are expected to include youths, multilingual communities, or individuals without specific knowledge or training in product use, the use of pictorials and symbols may be more effective [10]. If a target market is expected to have an increased degree of training and knowledge before product use (licensed or certified users), complex language may be considered more effective in expressing the risks present with product usage. An example of this would be industrial or laboratory equipment – such products are not marketed to home consumers, and professionally trained users (surgeon, professional engineer, etc.) may be expected to have a greater understanding of the language associated with specific risks and instructions on how to avoid them.

Standards. The efficacy of warnings as risk communications is dependent on the ability of the target audience – consumers of the product – to understand the dangers described in the warning. Intrinsic to this goal is the standardization of warnings. Standards not only regulate the method of communication, but the manner by which risks are to be communicated. Comprehension must be expected for the target audience in order for a warning to be considered effective.

One such standard, ANSI Z535, used primarily within the United States [11], specifies six sub-standards: (1) safety colors; (2) environmental and facility safety signs; (3) criteria for safety symbols; (4) safety signs and labels; (5) safety tags and barricade tapes (utilized in the instance of temporary hazards) and (6) product safety information in product manuals, instructions, and other collateral materials. These standards are established on the basis of human factors research and court case precedents, formally revised twice each decade. ANSI Z535 conforming signs use signal words – 'danger', 'warning', 'caution', (safety notice signs use 'notice' or 'safety instructions' specific to a situation) – accompanied by hazard details, consequences, and avoidance procedures. Figure 2 depicts a warning designed according to the ANSI Z535 criteria.

Fig. 2. A warning design according to ANZI Z535 criteria. The corresponding background color for "warning is orange".

International Standards. While ANSI Z535 may be effective within its sphere of influence, the United States is far from the only domain to have established a standardization of risk communication in the interest of public protection. International standards are set forth by the International Standards Organization; ISO 3864 generally corresponds, in effect and intent with the ANSI Z535 [7]. However, it is necessary to note that these documents do not coincide on all points. For instance, ISO 3864 uses the color yellow for all safety messages, while ANSI Z535 uses red for the most severely ranked safety risks, as well as prohibited activities and fire safety; yellow and orange are used for other warnings. Pictorials are encouraged whenever practical under ANSI Z535 in standard format of black graphic on a white background; whereas ISO formatted graphics refer to a mandatory action, a white graphic inside a blue circle; a prohibited action, a black graphic inside a red circle outline with slash; or a hazard identification, a black graphic inside a yellow triangle.

Closely related to the ISO 3864 is ISO 7010 [12]. The guidelines most recently released in 2012, define the manner of safety signs to be used for purposes of protection from accidents, fires, or health hazards, using ISO 3864-1 guidelines to establish the shape and color of each sign and ISO 3864-3 to determine the design of graphical symbols [13]. These standards were developed specifically to supersede language barriers, communicating potential risks successfully, regardless of the consumers' native tongue.

Corresponding Colors. One of the more prominent features of warnings is their corresponding colors. All colors used for the purpose of warnings tend to share the characteristic of high conspicuity. This is due to the increased efficacy of warnings associated with increased detection.

Safety Symbols. One of the most universal types of warning is the safety alert symbol. As symbols cannot be effective at communicating a message to their target audience, their prevalence and relative equality across communities are central contributors to the efficacy of this method of risk communication. An example of a safety symbol published by the ISO is depicted in Fig. 3 [12].

Fig. 3. Safety alert symbol

Pictorials. Pictorials are differentiated from symbols since they rely primarily upon visual imagery to convey information, but may be more detailed or less stylized than symbols, and may also include words or alternative methods of communication. As pictorials may also contain written messages, they are more capable of conveying explicit risks or instructions than symbols, which contain only an image [14]. Pictorials are used on medication labels in order to reduce miscommunications about prescribed dosages and instructions for use. Pictorials provide warnings that are comprehensible to a greater percentage of the population, especially those of an age, education level, or language fluency which may limit their understanding of written warnings or instructions. Although they have been found less effective for communicating complex or abstract risks, pictorials may be used with great efficiency and efficacy for communicating concrete risks or simple instructions that are widely comprehendible to the consumer public [15].

Examples. Pictorials and symbols can be combined on a warning label. This approach allows potential users to see the symbols which indicate that a hazard is associated with the product and provide more specific information about the nature of the hazards. For example, in Fig. 4, the triangular safety alert symbol precedes the signal word "DANGER" and the diamond symbols indicate flammable and contents under pressure. The pictorials provide the additional specific information about inhalation, explosion and fire hazards.

Fig. 4. Some warning labels combine both pictorials and symbols.

Pictorial risk communications are perhaps best exemplified by the recent push in many countries by the World Health Organization to increase consumer awareness of the health hazards associated with cigarettes [16]. These campaigns have resulted in the presentation of dangers in the form of graphic images placed upon cigarette packs and cartons with the intent to alert consumers of diverse cultural and linguistic backgrounds of the hazard. More basic pictorials are presented in the form of symbols, commonly found internationally: a red circle with a line through it is recognized to signal a prohibited action; a yellow sign outlined in black indicates caution regarding the symbol shown. standardized risk communications [12].

3.3 Other Types of Risk Communication

When an on-product warning label is not appropriate or possible, there are other methods available to communicate potential hazards.

Visual. Both traditional warning labels and other visual warnings rely on communication through written words. However, there are limitations to this approach if the consumer population is uneducated or unversed in the language that a warning or instruction is written in, or disinterested in reading information associated with potential product risks. Visual warnings include red, orange, or flashing lights [17].

Auditory. Auditory risk communications are less common than visual media [17]. Pedestrians are alerted by chirping traffic signals, while mass transit riders hear recorded instruction messages over a PA system. Oral risk communications are commonly found as recorded messages. These may be found on their own, or in conjunction with visual warnings such as in videos created to instruct consumers on proper product use. These risk communications may be as long or short as the hazards they communicate warrant: a toxic chemical spill within a factory will warrant a succinct evacuation message which includes no unnecessary wording, while an instructional video designed to guide users through the installation and startup of a new software product may last much longer, explicitly guiding users around multiple minor hazards which could negatively impact product performance. Other types of nonverbal warnings include sirens on emergency vehicles, car horns, smoke alarms, and back-up alarms.

Olfactory. Olfactory warnings are effective only if the scent presented is easily and widely recognizable as a warning and if the consumer has an effective sense of small (due to disease, illness or injury). Natural gas may be one of the most prominent examples of this phenomenon. While the scent of a natural gas leak is almost universally recognizable and always associated with a warning. However, natural gas is actually odorless. The scent the general public associates with natural gas is the chemical mercaptan, artificially added to provide an indication of a natural gas leak. There is a limitation to the efficacy of olfactory warnings in that many people temporarily or permanently do not have a sense of smell. For example, people with allergies or a cold may not be able to detect the scent of an olfactory warning [18].

4 Location

Risk communication depends on warning conspicuity in order to attract consumer attention. If a message does not attract the attention of a product user, the label is ineffective.

On-product. The most effective location for risk communication for consumer products is placed directly on the product, which can be applied to both tangible – through obvious means, such as a sewn tag on textiles or an adhered label on manufactured goods – and intangible objects, such as an insurance policy purchased through face-to-face meetings with an agent. Warning label placement and interaction with the warning have been shown to improve the efficacy of risk communication in attracting attention but also showed that no label was 100% effective in mediating safe user behavior [19]. Thus, placement of a risk communication is not sufficient by itself to promote safe practices and must be paired with effective methods of communication to influence user behavior.

Manual. Printed user manuals may be the least effective placement for successful risk communication that a manufacturer can rely on. Research published in 2006 indicated that the printed user manual is in fact the least likely medium by which consumers seek product information, used by an average of 3.16% of the product-using population. These consumers were more likely to use another of the surveyed options: asking others for help, searching online, or solving problems on their own [20]. Of those likely to consult the user manual, many do not read the manual from cover to cover. Manuals can be accessed on-line and because they are an important aspect of informing users who rely on them to search for specific product-use information, it is important that this information source, which is not limited by the length restrictions that a label has, provide complete safety and use information. At the present, manufacturers are required to place all on-product warnings within the manual as well, though the converse is not true [21].

Websites. Over the last two decades, companies have begun to place product warnings and instruction manuals on their websites in addition to the products themselves. This can be done in a multitude of ways, and is also found with intangible products. Software or media purchased online is unlikely to contain a warning present in the product itself, and as such will often direct users to the producing company's website for further instructions and warnings. Physical products have begun more commonly to use a similar strategy, including warnings and basic instructions with the product and instructing consumers to consult a website page for additional information. While risk communications placed directly on a product will be present for viewing each time a product is used, only a small minority of consumers can be expected to go out of their way to seek additional information online [22]. Online information should be in addition to, but not instead of, important risk communication on the product itself.

Packaging. Warnings should be placed on product packaging so the information is available to consumers at the time they are making their purchasing decisions. The potential time on-package warnings are available for viewing by consumers may be limited because common behavior is to remove packaging as disposable, and retaining only what is necessary for product function. Although there is no physical wrapping present for software or media purchased with a computer, many of these products will be prefaced with a warning before they are installed or downloaded onto a user's computer, requiring the purchaser to check a box verifying they have read the contents of a warning and agree. Such communications are actually inspected with great infrequency, with one study claiming as few as 3% of consumers read online Terms and Agreements contracts thoroughly [23].

Advertising. Some risk communications are found in advertisements. As these are designed to be a potential consumer's primary introduction to a product, they are regularly found only where explicitly required by law, often with overt attempts to downplay or disregard the message they communicate (see anti-warnings, Sect. 5). Manufacturers tend to design these communications specifically with a goal to prevent negative impacts on consumer consideration of the product in question.

5 Anti-warning: Downplaying Risk

Manufacturers have historically used two strategies to weaken the impact of warnings: (1) Warn inadequately or not warn at all; (2) Produce media that deliberately misrepresent dangerous products as safe in order to contradict warnings [24]. Anti-warnings are communications that may be used to downplay risks and assuage user concerns. Anti-warnings, contradictory to the name used here to describe them, tend to show more of a superficial resemblance to advertisements than warnings when they are presented on a product. As can be commonly seen in ads, whether they are roadway billboards, magazine spreads, or online, companies design these media formats to present information encouraging consumerism, minimizing negative factors such as risk whenever possible.

The design of anti-warnings extends beyond their location. Often, they contain written descriptions of the unsafe or inappropriate behavior they encourage. As this type of message tends to be regulated – if a safety risk is severe enough to warrant a regulated warning, there is commonly associated legislation restricting direct contradictions published by the manufacturer – anti-warnings are less likely to contain explicit instructions contradicting warnings, and more likely to present a message designed to attract consumers to the product. Depending on the product, this may be an emotional appeal or claim to greater happiness, attractiveness, entertainment, or health. Regardless of the exact wording, fonts will be large, bold, friendly or exciting, picked by the manufacturers for the purpose of attracting consumer attention and inciting positive reactions either consciously or subconsciously [24]. The pictorial format tends to be popular for anti-warnings, as it allows bright, optimistic, eye-catching imagery to be presented front and center, accompanied by simple, accessible messages designed to attract consumers. This image placement allows better communication for anti-warnings, as the use of imagery contradicting warning labels and safety communications is more common than directly juxtaposing written messages that directly negate each other [24].

While risk communications are sometimes worded so the average consumer does not understand them, anti-warnings are presented to not only encourage product purchase, but also discount the risks presented in warnings. As such, anti-warning labels can be expected to include common vernacular, and are more likely to be designed to appeal to the target audience on a more personal level than warnings, which in contrast, are often communicated in linguistics that appear to require an advanced degree to interpret. Anti-warnings tend to contain messages carefully worded to imply product attributes either opposing or negating the information conveyed by the risk communication [24].

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Soldier Protection of Staying in the Radiated Field Generated by Antenna of Selected Military Communications Systems

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Abstract. The article concerns problems of electromagnetic compatibility, and protection from exposure of electromagnetic fields of living organisms. The article mainly focus on the impact of electromagnetic fields coming from the Military Communications Systems for the soldier. Article presents the impact of electromagnetic fields for the living cells, characterized protection regulations from exposure of electromagnetic fields at the Military Operations. Article shown the results of measurements and analyzes the values of the intensity of electric and magnetic fields coming from backpack radio used by the soldiers.

Keywords: Soldier · Electromagnetic compatibility · Electric fields · Military systems · Radio-station

1 Introduction

In the era of modern military operations it made it necessary to develop communication systems which meet the requirements of use of communication at all levels of operations. In view of the increasing demands for communications immunity to various factors, an important topic has become the safety of persons operating a communications system. This publication shall be analysis of issues related to the safety staying close to the antennas of military communications systems. The question is whether it is safe?

2 Impact of High Frequency Electromagnetic Fields at Living Cells

The military telecommunication systems in the sub-divisions used in the radio band from 1.5 MHz to 88 MHz (radio battlefield). Radio stations battlefield sub-divisions used in the army are working in networks and radio directions in two frequency ranges:

- in the range 1.5 MHz–30 MHz, short-wave radios,
- in the range of 30–88 MHz, ultra-short radio.

Ultra-short-wave radio are designed to provide communications for the small and medium distances (up to 35 km). Communication range of VHF as a whole covers the

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demand for transmission of information at the level of sub-division. Radiation power of these radio stations is 0.5/5/10 W. At the same time, these radio stations, as shown in Fig. 1, are used in direct contact with the soldier.

Fig. 1. View of radio stations on the back of operator

Concern primarily the potential for harm field generated by the antenna of radio stations located next to the body of the operator. There are fears without rational grounds because the current state of knowledge of the impact energy of electromagnetic pulse on living organisms giving the impression that the electromagnetic energy in any amount acts on the human body. This effect is harmless until its effects are within the limits set by the adaptability, compensation and regeneration, but it may be harmful after crossing the limits of tolerance of functional system. First hand, it should be possible communicate with stations that can be in the direction of where the head and on the other hand, the head should be illuminated the minimum power level and especially those elements of the bones head, brain, and skin that are characterized by high thermal absorption coefficient (respectively 14.6, 8.05, 4.42 $mW/cm^2\ {}^\circ C$). In the currently used radio stations substantial part of the radiated power (50%) is absorbed by the body of the wearer. This can adversely affect their health.

Therefore have been introduced protection zones in the vicinity of sources of fields, in order to protect from harmful electromagnetic radiation characterized by a dose of radiation and index of exposure. Determination of protection zones in the working environment is closely associated with a dose of radiation and index of exposure.

Permissible dose of electric field (or magnetic) is considered as the value of the product of the square of the electric field (or magnetic), demarcating the danger zone from the intermediate zone and expressed in hours operating time per person exposed to the effects of electromagnetic radiation.

3 Protection from Ionizing Radiation Power at the Location of Operations Military Communications Systems

Regulation to protect soldiers against the effects of electromagnetic radiation in the workplace military communications systems deal with defense standards. They introduce levels of spurious emissions and immunity of electromagnetic exposure. In not regulated aspects by the standard we use civilians requirements with the exception of the permissible limit of SAR, which regulates the standard STANAG 2345 Edition 3 adopted February 13, 2003 year. In addition, any regulations are not apply in workplaces equipped with electromagnetically sealed room (containers), guaranteeing complete isolation from electromagnetic fields coming from the antennas. Personnel then residing in the during transmission outside of containers at your own risk. Range of regulations on electromagnetic emissions radiated has been divided into three areas. The frequency of the radio station of the battlefield is an interesting one area, the requirement applied to radiated emissions coming from equipment and shielding subsystems all connection cables, antenna permanently attached to the EUT (standby/reception receivers and transmitters) in the frequency range of 10 kHz–18 GHz. This standard limits are given the intensity of electric and magnetic fields for the operation, as shown in Fig. 2.

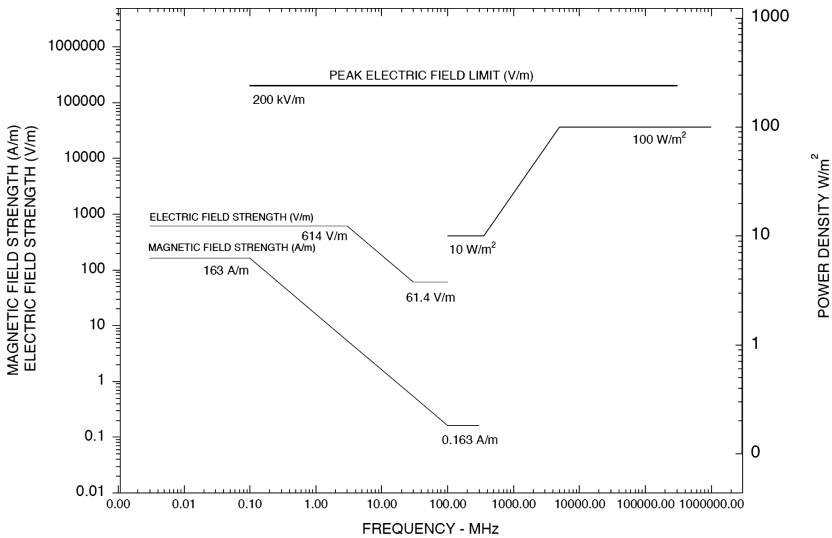

Fig. 2. Permissible values of intensity of electric and magnetic fields [4]

4 Measurements of Electromagnetic Fields Components

In terms of operating frequencies, the safe limits in the range of 30 MHz–87.975 MHz is considered the intensity of the electromagnetic field on the edge the intermediate zone and a safe zone, which meet the requirements of STANAG 2345.

In order to perform a reliable measurement of the intensity of the electromagnetic field, the PN-T-06580-3 standard requires to follow a few general conditions of measurements:

- measurements of electromagnetic fields should be carried out only by persons who are aware of the dangers that exist while performing measurements are not any health contraindications to perform such measurements, and have actually confirmed qualifications in the metrology field of measured fields;
- the field meters used to measure, shall be comply with the relevant standards, or provide other equivalent measurements;
- during measurements we must locate the source of electromagnetic fields, as well as the distribution of fixed and variable staff positions and define the area of measuring the intensity of electric and magnetic fields of the recommended standard uncertainty - not exceeding 20%;
- field measurements carried out in these operating conditions sources, at which a given measurement area are the maximum possible intensity of fields used during normal operation of the sources located in the area of measurement;
- measurements should be carried out in an environment deprived of interferences and disturbances from the environment (electromagnetically sealed room) and the of uninterrupted by the presence of people [3].

The PN-T-06580-3 standard also regulates other aspects electromagnetic fields intensity measurements, such as the designation of protected zones existing at the measurement, estimation of time of exposure being in the zones.

Before measurements should also determine the measured values during the tests. According to PN-T-06580-3 standard for frequencies up to 300 GHz should take measurements of electric field strength. In the range up to 3 GHz we must done an additional measurements of the magnetic field. For the purposes of this article identified the following measured values:

- the effective value of the electric field strength, expressed in [V/m] and [dBV/m];
- the effective value of the magnetic field strength, expressed in [A/m] and [dBA/m];

The potential measurement uncertainties may arise from:

- uncertainty of used instrument;
- interaction between the instrument and the source of measured field;
- the impact of temperature;
- the impact of air humidity;
- the frequency of measured field and the frequency used instrument.

Measurements of the intensity of electric and magnetic fields should be done in the area in which all space can be considered as a space position of in an environment Sources of fields in which you can stay employees while working.

Basically, the measurements the field strength should be carried out in primary and secondary verticals of measurement. Verticals should be numbered and their location indicated on the situational plan. This location should match the distribution of staff positions, the basic vertical measurement must be selected along the axis of body or head of the employee. The verticals measurements should be performed in such a way as to determine the maximum field strength, able to work on standing employee and at least up to 2 m ± 0.05 m. If the measurement would be performed outside the anechoic chamber, verticals should be set up at distances of not less than 0.15 m ± 0.02 m from metal structures, and other objects that could affect the field distribution in the area of measurement - while keeping the requirements of the distance of the objects according to the instructions of the measuring instrument. But if the instruction is not included this information, the minimum measuring distance should be not less than two - three times the maximum linear dimension of the probe. Additionally it allows the design of the device and the same probe at the time of measurement is allowed to perform measurement at a distance of less than 0.15 m - in particular to evaluate the exposure of the limbs.

Due to the one-man operation backpack radio stations, in measurements will be used one vertical measurement representing the service directly at the antenna and one vertical measurement, set at a distance of 3 m from the antenna, representing a single soldier stationed nearby. In addition, they will perform measurements directly to the same radio stations. The whole measurement is carried out in an anechoic chamber for several selected operating frequencies out of all available bandwidth operation. The frequency range of radio stations do not require additional attenuation ferrites floor.

The laboratory stand for the backpack radio stations measurement, with measurement fulfill the criteria, there is shown a top view of the Fig. 3 and in an oblique in Fig. 4.

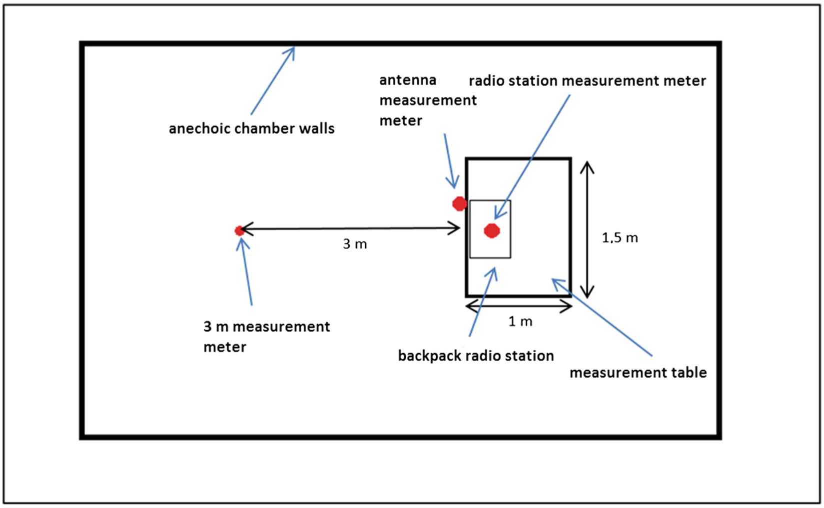

Fig. 3. The laboratory stand for measuring the intensity of the electromagnetic field of backpack radio stations - view from the top

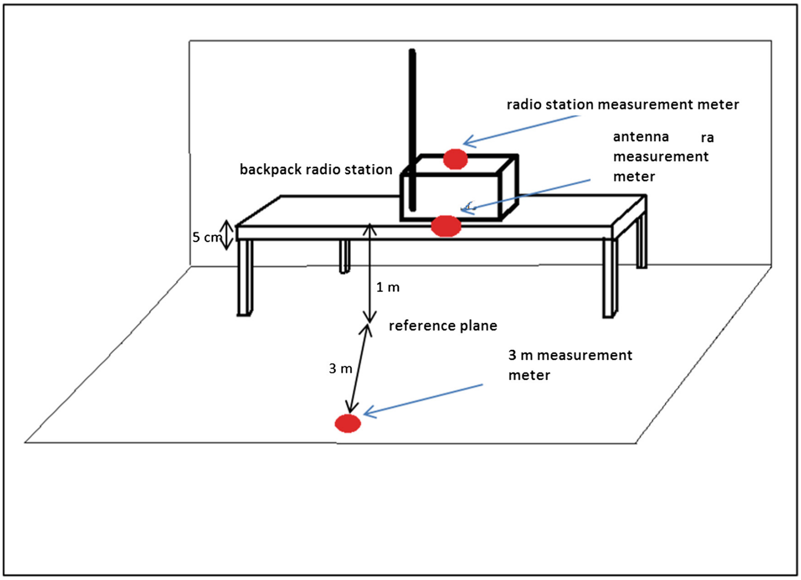

Fig. 4. The laboratory stand for measuring the intensity of the electromagnetic field of backpack radio stations – a side view

The measurement stand should be the following:

- wooden table with a height of 1 m from the ground reference. Table height represents the height at which there is a radio station - on the back of a soldier kneeling. Table size should be as small as possible, preferably 1 m to 1.5 m from the top with a thickness of 5 cm.
- digital meter of electromagnetic fields, equipped with a field probe for measuring the instantaneous values components of electric and magnetic field. It is accepted stationary meters and hand meters, making sure to pay attention to the control of distance measurement using the hand meter.
- anechoic chamber.

Radio stations that are subjects of research have been programmed to work at a fixed frequency. For radio stations backpack was the mode HLG, the well could be used HLC mode. The decision on HLG was dictated by the duration of the programming radio station. This time, in turn, should be as short as possible, because it limits the total exposure of the human body to electromagnetic radiation. Finally adopted the following configuration settings radio stations:

- operating frequency: 30.000 MHz–87.975 MHz;
- output power: 10 W (maximum available);
- selected measurement frequency:
  - 30,000 MHz;
  - 44,475 MHz;
  - 58,975 MHz;

– 74,475 MHz;
– 87,975 MHz.

In the measurements experiment were carried out in anechoic chamber shown in Fig. 5 by means of electromagnetic fields meter Wandel & Goltermann EMR-300. Measurements of the intensity distribution of the electric and magnetic field are made at different distances from the antenna radio stations and different height. For the height of reference adopted at the height of the radio station located, then increased height from 0 m to 2 m along the height of radio stations antenna.

Below in Figs. 6 and 7 presents the results the intensity of magnetic and electric fields at different distances from the antenna when the radio transmitting and receiving. Additionally, the presented graphs indicated permissible level of electromagnetic radiation defined in the document STANAG 2345 (Fig. 2).

Fig. 5. View of anechoic chamber with radio station during of measurements

On the basis of the measurements it can be concluded that with each case and each measurement exceeding the permissible levels of electromagnetic radiation for both the emissions from the same radio station, and also on antenna (Fig. 7).

In the case of measurements of the magnetic field intensity at a distance of 0 m from the antenna, permitted levels of RF is not exceeded for the lowest frequency of working at a height of 2 m from the reference level. Basically, for each height appears to be increase value of the electric field in the central part of the band and its decrease for the highest frequencies. Very large fluctuations in value we observed for a height of 1.5 m. It can be explained by the repeatability error settings meter at the time of measurement. Entirely different results were obtained for measurements at a distance of 3 m from the radio antenna. In this case, the results are like most normal scales over the band and each height. You can see very similar values of the electric field at every height, in addition, the same levels in the entire band evenly.

In the case of measurements of the magnetic field strength at a distance of 0 m from the antenna, permitted levels of RF is not exceeded for the lowest frequency of working at a height of 2 m from the reference level. Basically, for each height appears to be increase the value of magnetic field strength in the middle of the band and the decrease the highest frequency. Large fluctuations in value observed for a height of 1.5 m can be explained repeatability error settings meter at the time of measurement.

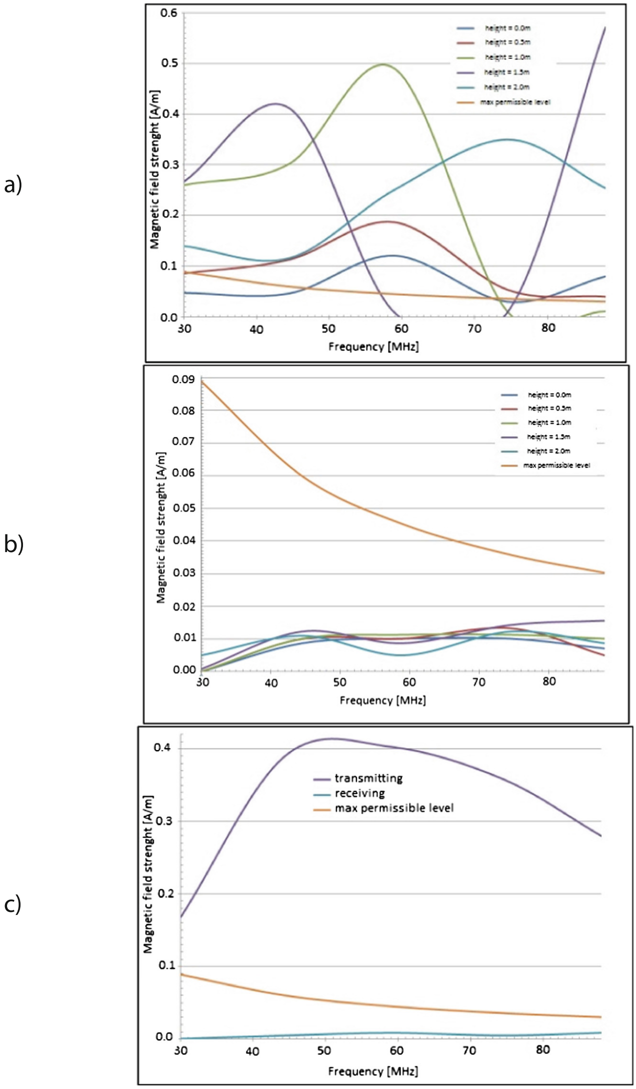

Fig. 6. The plot of magnetic field strength of radio station measured at a distance of (a) 0 m from the antenna, (b) 3 m from the antenna (c) during transmission and receiving

Completely different results were obtained for measurement at a distance of 3 m from the antenna radio. In this case, the results are as much as possible in the standard in the whole band and each height. It can be observed very similar values of magnetic field strength at each of the heights, in addition to the same levels they are highly uniformly throughout the band.

Measurements of the magnetic field the same device radio station have revealed that the levels of emission limit of the magnetic field are not exceeded only when the a)

b)

c)

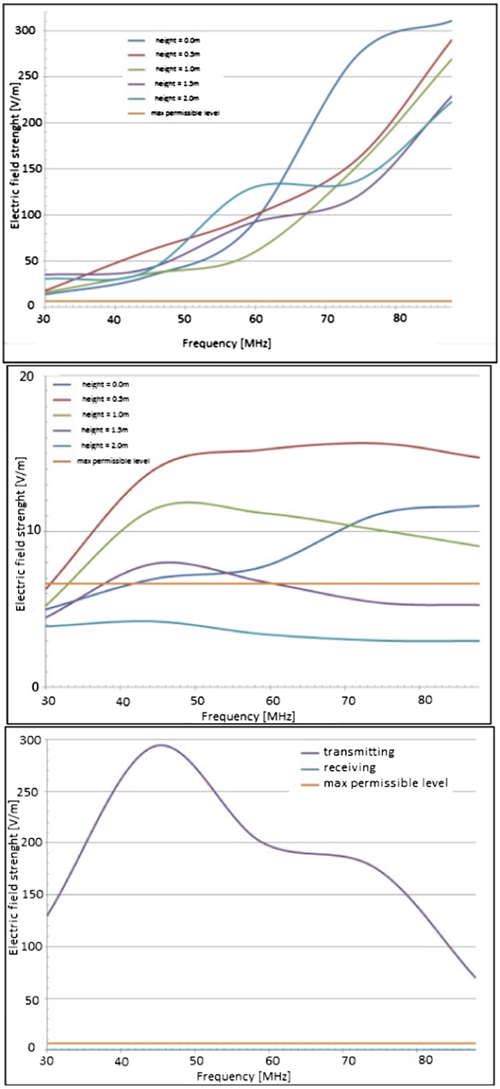

Fig. 7. The plot of electric field strength of radio station measured at a distance of (a) 0 m from the antenna, (b) 3 m from the antenna (c) during transmission and receiving

radio is not transmitting. The radio station emits a very low value of field strength in the whole band, and when we pressing a button on the handset the power of field strength are increments. For frequencies of 30 MHz, this level is exceeded twice, while increasing the frequency will increase the field strength level until they reach-frequency 58.975 MHz, only to decrease slightly.

In the case of measurements of the electric field at a distance of 0 m from the antenna, the maximum permissible emission levels of the electric field is exceeded over the operating band and each height. For the lowest frequencies, i.e. 30 MHz and 44.475 MHz, this level is exceeded several times, and then begins increase very sharply with increasing frequency, reaching the highest value for the lowest measurements made.

Measurements made at a distance of 3 m from the antenna presented a slightly different situation. Well, in a distance of 3 m from the antenna, at a height of 2 m from the ground, horizontal electric field is below the permitted maximum.

It should be emphasized that the guidelines for exposure to radio waves used by the physical quantity is abbreviated Specific Absorption Rate (SAR), which determines the specific energy absorption rate. The specific rate of energy absorption is a measure of the rate at which energy is absorbed by the body when it is exposed to radio frequency electromagnetic fields. It is defined as the power absorbed by the mass of tissue of the human body, and its unit is the watt kilogram (W/kg).

Specific Absorption Rate can be calculated from the electric field from the relationship:

$$SAR = \int_{sample} \frac{\sigma(r)|E(r)|^2}{\rho(r)} dr \tag{1}$$

where:

- σ - conductivity of the sample,
- E - the value of the effective electric field,
- ρ - density of the sample.

On the basis of this relationship which takes into account the exposure time, its importance, the mental state of the radio operator of the battlefield, we can say whether they will be exceeded dose of radiation.

In the case of Specific Absorption Rate, according to the standard STANAG 2345 the maximum valueis 0.4 W/kg in the frequency range of 100 kHz–6 GHz. This level has been established as a tenfold lower Specific Absorption Rate value of 4 W/kg, which is the limit value at which followed potentially an irreversible biological changes of the human body [4].

5 Conclusions

Taking into account the analysis undertaken of safety aspects stay in the electromagnetic field from antenna of military communications systems and the results of measurements of the field strength of the electromagnetic radio battlefield was found high health concerns supports radio station. The radio station with a power of 10 W, while in receive mode only meets safety standards for both located near the radio station, as well as for wearing it on your back. Unfortunately, at the moment of pressing button on handset causes a large emission of electromagnetic fields (high level of magnetic field strength, very high electric field), which certainly in the long and speculative and short-term may cause negative or detrimental effect for the human body in a direct contact with the radio station and included with the antenna.

Based on measurements taken at a distance of 3 m away from the radio station and antenna were found much lower level of intensity of the electromagnetic field. However, it is not low enough to distance this be considered a safe zone.

Broadcasting radio station on your back with 10 W carries a risk of injury. It would be useful to limit dwell time in the vicinity of radio station, especially if the radio station is often transmitting.

The research was conducted for radio stations with maximum power “only” 10 W. The Polish Army backpack radios are available with much higher maximum power output. In addition, the impossibility of carry out measurements of SAR, it became impossible to carry out a full analysis of the risks of working in direct contact with the radio station working with the power of 10 W.

In summary, based on our review of the safety issues we developed the following recommendations for working with radio station backpack:

- Avoid approaching the radio stations at a distance of less than at least 3 m, and if this is not possible, go away for a maximum offered by the handset cable distance;
- As much as possible to avoid transmission of radio station located on the back;
- use, as far as possible, with the lowest possible power output offered by the station;
- limit exposure time near the radio stations if the radio often and long passes in the transmission mode.

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Work Automation and Psychophysical Hazards in Employees' Opinion

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Abstract. This article aims at demonstrating employees' opinions on consequences of changes in psychophysical strain on employees, resulting from anticipated changes in the scope of work automation. The authors present the theoretical directions of research connected with automation issues and transformations resulting from that process, with regard to the risks of hazardous and onerous factors. This article in particular addresses the psychophysical strain. In the subsequent part of the article the authors discuss the research methodology and analyze the research results. The last part of the article contains conclusions derived from the analysis.

Keywords: Work automation · Psychophysical hazards

1 Introduction

The progress of computerization and IT systems in the 1980s led to a significant change in the nature of the workplace, leading to reconfiguration of work systems and employment relationships. The paradox produced by these forces is striking: employment relationship is becoming more market-mediated while at the same time business performance in an increasingly knowledge-driven economy requires high levels of trust, commitment, information sharing, and coordination. What is particularly important is that internationalization of production processes and the ubiquitous application of information technology in production of goods and services are important sources of competitive pressure on firms. However, they are not the only sources of heightened competition among firms. Vertically integrated organizations and internal labor markets are being replaced by arm's length relationships and subcontracted work designed, in the absence of strong unions, to intensify the work [1]. Outsourcing and off-shoring are in use, which means moving jobs to workplaces where labor is cheaper. Due to computer software and progressing automation and robotization, labor shifts from human work to technical work [2]. Both the technological revolution and globalization have transformed the competitive landscape and the situation of the employee [3].

Digital technologies are doing for human brainpower what the steam engine and related technologies did for human muscle power during the Industrial Revolution. They allow us to overcome many limitations rapidly and to open up new frontiers with

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unprecedented speed. Their impact cannot be overestimated. However, there is a social price for that referred to as 'unpleasant side effects'. Digital innovations contribute to the stagnation in average incomes in the United States and to the disappearance of many middle-level jobs. The number of people in employment is getting lower, as technologies have decreased the demand for low-skilled information workers [4].

The objective reality requires that the problem should be viewed from the perspective of employees who expect acceptable work conditions and stability of income sources. Therefore, the authors decided to find out employees' opinions on the threats posed by increasing automation and its expected effects on work conditions.

2 Research Problems

2.1 Automation as the Contemporary Focus in Labor Research

Digitalization of occupational life is becoming a fact. Communication in both private and occupational life via Web Services 2.0, or using more and more sophisticated software for social cooperation in the form of private and business networks have become a standard. The Digital Workplace concept addresses the changing conditions of knowledge-based labor. It meets the technical and cultural requirements as well as any necessary adjustments to the current labor environment [5].

The reasons for the decrease in the number of jobs have been sought since the 1980s. Especially ever since the end of the Great Recession, the rate of creating jobs has not been keeping up with the population growth. Profits made by companies have doubled since 2000, however, the average income per household (inflation-adjusted) has fallen from $55,986 to $51,017. At the same time, the share of corporate profit after tax in GDP rose from ca. 5 to 11%, while the share of employment-related costs in GDP dropped from ca. 47 to 43%. Somehow, companies make more profit employing fewer people. The number of jobs requiring low qualifications has been decreasing dramatically and faster than the rate of creating new ones. Research studies show that so-called routine jobs (bank teller, machine operator, dressmaker) began to fade in the 1980s, when computers first made their presence known, and the rate has accelerated: between 2001 and 2011, 11% of routine jobs disappeared [4].

The focus in the search for answers to the research questions has moved from the macro level to the level of jobs. Frey and Osborne have published a quantitative and qualitative method to specify the probability of replacing human labor in a given job and specialization with computer software (digitalization). The authors used the O*NET database of 903 occupations, comparing the data to 702 occupation descriptions (Standard Occupational Classification). That gave Frey and Osborne a lot of detailed descriptions of different tasks related to an occupation, since O*NET has detailed descriptions of "direct work activities" included in each of its occupations [6]. Then they distinguished three areas of human activity where computers must perform tasks cheaper and with comparable quality before they start replacing people. The computerization bottlenecks were then divided into subdomains. The set includes: perception and manipulation (comprising the subdomains: finger dexterity, manual dexterity, cramped work spaces and/or awkward positions), creative intelligence (with originality and fine art) and social intelligence, comprising social perceptiveness, negotiations, persuasion, assisting and caring for others. Then 70 occupations were singled out as the ones bound for computerization, and subjective measures of susceptibility to computerization were determined (being the value of 1 or 0). "Probabilistic classification" was used for the algorithmic part of the job. Vectors for 70 occupations were determined by means of the multiple method. The results show that there was a fairly systematic relation between the data in the 9-data vector and the labels and as a consequence the P(y) probabilities. The fuzzy set theory assumptions were used for calibration. According to Frey and Osborne, occupations showing a probability of computerization below 30% are considered to be at low risk, whereas occupations where that probability exceeds 70% are deemed to be at high risk.

Research results show that 47% of total US employment falls within the high risk category, meaning that associated occupations are potentially automatable over some unspecified number of years, perhaps a decade or two [6]. The corresponding share for Finland is 35% and for Norway 33%, i.e., 14–16% points less than in the US [7]. In the UK, 35% of jobs are at high risk of computerization (though differences between the UK and US classifications mean that the figures are not directly comparable). The results suggest that as technological capabilities expand and costs decline, we can expect developments like Machine Learning and Mobile Robotics to gradually replace labor in the same wide range of occupations as in the US, spanning transport, production, construction, manufacturing, services and sales [8].

Researchers point out to the need to develop the research methodology. This pertains especially to the ways of assigning probabilities for a certain outcome in connection with an occupation based on the characteristics of that occupation, and subjectivity in specifying susceptibility for automation. Some researchers point out the differences in task defining, which is one of the key issues decisive for the methodology correctness [9].

This study focuses on analysis of employee opinions regarding labor automation and related threats identified by them.

2.2 Psychophysical Factors in the Transformation Perspective

Labor being part of human activity is subject to changes resulting from the development of technology, knowledge and culture. From the onset of industrialization, labor study focused on the following archetypes: mechanistic (simplification, specialization and repeatability of work), motivational (enriching the tasks, autonomy, task diversity), perceptive (decreasing the information as a result of increased machinization and mechanization as a factor of decreasing the probability of errors, accidents and mental overload) and biological. The last one emphasizes the mental and environmental stressogenic factors and increased importance of the factors to decrease physical discomfort and stress. However, the authors of contemporary concepts of job design preserve the classical assumption that work may be divided into three major constituents: work complexity, social environment and physical environment [10]. Still, they also point out to the fact that physical requirements are ignored in the latest concepts of job design, which is inconsistent with the results of the research studies completed so far, as the research results have shown a significant level of correlation between such elements as physical activity, work conditions, applied technology or ergonomic features, and human labor results [11]. Impact of work on an individual is also subject to change. Therefore, it is still important to pay attention to the physical characteristics of work, taking into account work conditions, ergonomics, physical requirements, strain and activity level (understood as mental strain) as well as equipment and tools [12]. This approach to job design is close to ergonomic design which is focused on the human factor aimed at avoiding unfavorable health consequences resulting from occupational hazards [13]. From the perspective of labor safety, a human in the work process is exposed to hazardous (leading to injuries), onerous and harmful factors. Hazardous factors are those which may cause an injury to a human, i.e. an accident at work. The literature specifies several major groups of such hazards:

- hazards caused by sharp or protruding objects,
- hazards caused by movable and loose objects,
- risk of electric shock,
- risk of scalding,
- hazards connected with people movement,
- risk of fire and/or explosion.

Onerous factors are those which may lead to decreasing the physical and mental ability of an employee. Harmful factors, in turn, may cause poisonings, and even death. Comparison of various approaches to job design, modifying the conditions of the material environment in which the work process takes place, shows the importance of setting appropriate criteria for employees and employers [14, 15]. The research studies results show that the most significant criteria for employees include tiring posture (ergonomics), psychosocial strain, risk posed by machines and work environment factors (work conditions).

Due to the transformations in the area of labor it is also worth noting that the length of occupational activity of people is being extended due to the population ageing process. Thus, the changes taking place in technology are also used at workplaces by older and older employees [16]. The assumption that application of IT at work will help reduce physical strain and improve working conditions for mature age people is correct. However, on the other hand, elimination of physical strain may have an adverse effect on a human organism, e.g. leading to muscular dystrophy [17], whereas the amount of processed information and stress may contribute to increased mental strain [18].

Research studies conducted by EU-OSHA have shown that currently a half of employees considers work-related stress to be a serious problem. Apart from mental health related issues, the results of stress experienced by employees include serious problems connected with physical health, which are manifested e.g. by the circulatory system diseases and complaints related to the muscular and skeletal system. The specialist literature more and more often focuses on analyzing the effects caused by stress.

3 Methods of Research and Data

The research study was carried out using the originally developed questionnaire called WAQ (Workplace Automation Questionnaire). The questionnaire contains four parts with content-related questions, as well as the social and demographic data of the respondents. Part one contains data regarding tasks performed in a given job, broken down into constituent actions and the percentage of time they take within one month's working time.

Part two is aimed at acquiring information on the manner of performing the work (manually, by machine, by computer, by decision-making), task complexity level according to ILO typology (simple, moderately complex, complex, creative), requirements regarding qualifications, cooperative requirements (from autonomous actions to contacts with institutional environment), and the employee opinion on the current level of computerization of the activities and anticipated changes in the time horizon of 3–5 years.

Part three contains information on Frey and Osborne criteria regarding computerization bottleneck subdomains. The respondents evaluated the presence of the individual nine subdomains in the activities they performed in their jobs, using the 5-item Likert scale, where 1 = not present, 2 = present to a small degree, 3 = present at a medium, perceptible level, 4 = present at a significantly perceived level, 5 = very often and systematically present.

Part four comprises employees' evaluations of factors identified in their jobs, which may cause a decrease in their mental and physical abilities or an injury and which may lead to developing an occupational disease. Further on, the respondents also evaluated a possibility that the aforementioned risks might be eliminated in case of the job automation in the future. The respondents were also asked to assess whether automation of their job in the future might lead to its liquidation. As for this part, the 7-item Likert scale was applied, where: 1 = irrelevant, 2 = no impact, 3 = rather no impact, 4 = indifferent (neither yes nor no), 5 = perceivable impact, 6 = significant impact, 7 = powerful impact. The questionnaire was supplied along with instructions on how to use the scales.

All the surveys were pilot studies. The studies regarding the job characteristics involved the population of 373 employees, and 320 questionnaires were verified as correctly completed. The internal coherence level was very high for the studied population, as Cronbach's α for the characteristics ranged from 0.74 to 0.62 regarding the workplace.

The respondents were sampled purposively. 64.7% of the studied population were women, 63.4% of the respondents were aged from 20 to 30, 42.8% of the subjects had been working for 2–5 years (further 38.4% of respondents had been working for more than 6 years), 61.6% had a university degree, 77.8% of the respondents lived in cities, 46.9% worked in the service sector, and 34.1% in commerce. Thus, the respondent group mainly consisted of women – young city dwellers with higher education, with diverse work experience lengths, working mainly in services and commerce. The information was obtained from the occupational groups which will be experiencing the processes of accelerated automation in future careers.

In accordance with the adopted research procedure, the jobs were divided into three generic groups: jobs related to services, jobs related to production, and administrative office jobs in all industries and sectors. This methodological approach was aimed at verifying whether white collar jobs, which are the most affected by the digital workplace pressure, constitute a link between two kinds of jobs representing subsequent stages of development according to Clark-Fisher three sector classification, i.e. industry and services.

4 Discussion

The first of the researched elements was finding the respondents' opinions on the characteristics specified as work subdomains. The research results have shown a moderating impact of white collars on the level of finger dexterity (FD), manual dexterity (MD), cramped work spaces (CWS) and/or awkward positions, i.e. all the three subdomains belonging to the domain of Perception and Manipulation. The fourth subdomain is Negotiations (NG), being part of Social Intelligence (Fig. 1).

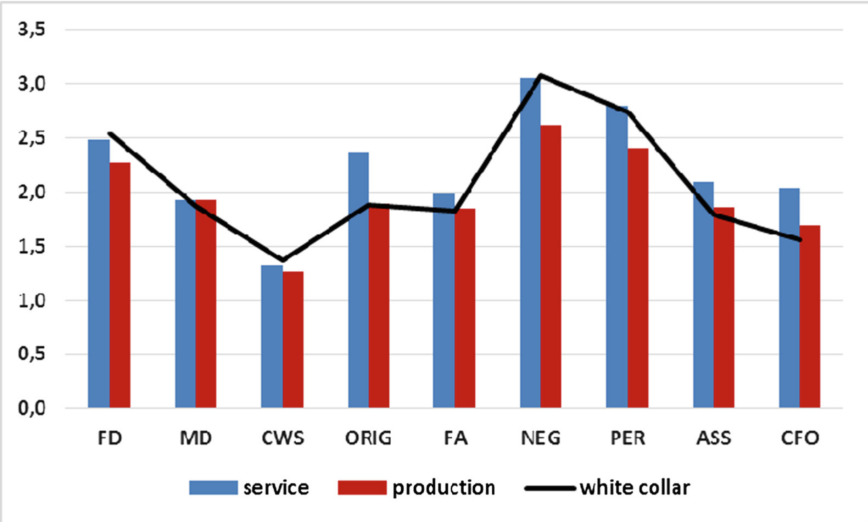

Fig. 1. White collars' opinions (black line) as a bridge between production and services employees in the computerization bottleneck subdomains system (5-item Likert scale). Source: research results

The research results have demonstrated an interpretation paradox, often found in social science research. In this case there is a reorganization paradox, in which introduction of new solutions leads to the need for adaptive and innovative reconstruction of the solutions used so far and for redesigning the methodology of actions. Progress in software development changes the work organization in white collar jobs and the communication system.

Also, new requirements arise in connection with the need to agree on various aspects of coordination and the roles of job positions in the work flow systems. Therefore, the Negotiations subdomain is of prevailing importance. The obtained research results have demonstrated that as for the remaining elements, i.e. in the Creative Intelligence domain, and also in Social Intelligence, service sector employees' opinions set the leading trend. The values of indicators for production workers show a reactive character, as they are lower from 0.1 to 0.5 compared to the other groups. Only in the case of the Creative Intelligence domain the white collars' and production workers' opinions are at the same level. This proves that the people do not feel free to take creative actions, and it's the evidence of dominating procedures that force the employees to take a rigid approach.

Figure 2 presents the results of the survey on the current and future automation of jobs and occupational risk. As mentioned above, the respondents were divided into three groups reflecting the occupational ranges and specializations. According to the respondent group working in the service sector which is expected to provide the highest employment in the future, their work automation is currently at the level of 71.1% of the average working time. The respondents working in production assessed the automation level similarly – 69.9%. But the decidedly highest automation of work – at the level of 81.4% – was reported by administrative office workers.

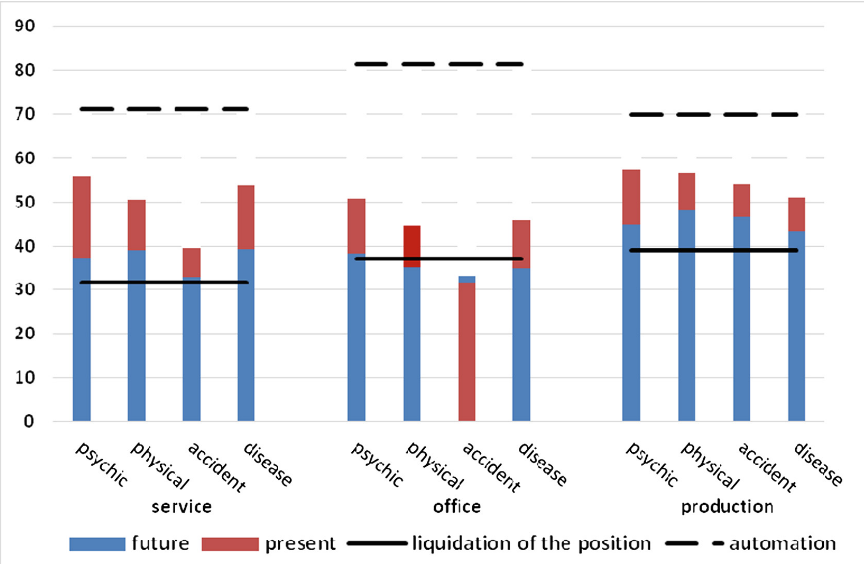

Fig. 2. The percentage of the value of the respondents' opinions on work automation and psychophysical hazards. Source: research results

The surveyed employees were asked whether the automation process would lead to liquidation of their jobs within 3 to 5 years. The respondents working in services anticipate the lowest level of jobs liquidation over the set time horizon: 31.8%. A higher rate of jobs liquidation is predicted by administrative workers: 37.1%. And the highest level of jobs liquidation (39.1%) is expected by production workers.

The study of the current and future occupational risks perceived by the respondents shows diversity in terms of work automation process. In the groups of service and production workers, there are opinions that there is a trend to reduce all risks in the future: mental and physical risks, risks of injury in connection with probability of accident at work and risk of developing an occupational disease. The administrative office workers group, in turn, believe the trend will be maintained apart from the injury factor, which is currently lower than the one expected by these respondents in the future. This results from the more and more numerous injuries connected with e.g. forced sedentary position at work, failure to provide ergonomic work stations, and the increasing occurrence of physical injuries such as carpal tunnel syndrome, tennis elbow or vertebral column injuries.

5 Conclusions

This research study is merely an initial diagnosis of a specific state of opinions held by employees on work automation processes and potential psychophysical risks, which in the respondents' opinion may arise as a result of introducing the Digital Workplace. This article shows the main assumptions of the quantitative and qualitative methodology developed for the purposes of determining the probability of automating any individual jobs and occupational specializations. The results of the employee survey were presented with respect to that.

The authors emphasize the need to improve the methodological solutions regarding both the automation measurement and employee opinions analysis. It is also necessary to note that the methodological proposals of theoreticians pertaining to some elements such as e.g. creativity, refer to the examples of freelance professions and/or creative professions, in which case autonomy and creativity are their essence. Therefore, the theoretical recommendations may not fit the other occupations [19].

The presented data indicate the leading opinion-forming role of service sector employees within the scope of Creative Intelligence and Social Intelligence (apart from Negotiations). White collars are a group which adapts and imposes new models of the Perception and Manipulation domains, as the changes evoke the need to reconstruct jobs in that regard.

The respondents in all the occupational groups involved in the study perceive a threat in the work automation process in view of a possible liquidation of some of the jobs in the future. As a result of the technical changes anticipated in the academic literature, there will be a relative growth in the demand for highly-qualified workers and a decrease in the demand for less educated workers whose work is based on routine mental and physical tasks. Over the next decades it is expected that about one-third of all currently existing jobs will be liquidated. Although the respondents working in the service sector are the most optimistic in view of their jobs liquidation as a result of work automation process, innovations pertaining to services will be the biggest threat for occupational safety. This results from the lack of experience in the area of human - robot (machine) interactions in professional services and it will require specifying legal liability for any accidents e.g. in public space.

The analysis of the research results has shown that employees in general perceive a link between automation and reduction of occupational hazards in the area of mental, physical, accident and disease risks. Robotics-assisted automation may therefore be used in the case of work conditions that are too difficult or dangerous for a human. Moreover, in view of the population ageing, robots may be a solution to the problem of the growing deficiency of physical workers.

Research studies indicate that in the near future the psychophysical risks connected with occupational work will be a major challenge in the area of occupational health and safety, as these issues have a significant impact on employees' health and the condition of organizations and national economies. Surveying employees' opinions with regard to their feelings pertaining to work environment hazards resulting from work automation provides one with a possibility to introduce appropriate tools for workplace risk management and improving the work safety culture.

It should also be noted that historically the development of new technologies brought not only benefits and new possibilities, but also threats and costs. It is generally thought that the pace of changes is increasing and it will be more and more difficult to predict future changes, especially in the area of automation and robotics.

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Is It Smart to Use Smartphones to Measure Illuminance for Occupational Health and Safety Purposes?

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Abstract. This study reports on the accuracy of smartphone-based illuminance measurement applications and whether they may be employed for occupational lighting measurements. A sample of nine mobile phones on three platforms (Android, iOS and Windows) was assembled and 14 apps were selected for testing. Testing conditions comprised four pre-specified illuminance levels (300 lx, 500 lx, 750 lx and 1000 lx) accomplished with three light sources presenting different Correlated Color Temperatures (2700 K; 4000 K; 6500 K). The results reveal extremely variable and sometimes large deviations from the reference levels and suggest smartphones are not appropriate for use in occupational lighting assessments.

Keywords: Light · Measurement · Applications · Mobile phones · Accuracy

1 Introduction

Despite of being mostly known for its visual functions, light also has biological effects and plays an important role in emotional perception. Therefore, poor lighting conditions in the workplace can adversely affect health, safety, and job performance. For that reason, light is often measured in occupational settings and in case of inadequacy; it may be improved both in qualitative and quantitative terms. Occupational lighting needs depend on factors such as nature of the job, workers' age, individuals' visual acuity, properties of work surfaces and general work area. International standards, namely EN 12464-1:2011 [1] and ISO 8995-1:2002 [2], provide guidance regarding lighting characteristics according to the type of activity being performed.

The most commonly assessed photometric measure is illuminance, which represents the amount of light falling onto a surface at a certain distance from a light source. It is traditionally measured with a dedicated lux meter in lux (lx) or foot-candle (fc) [3]. This particular type of measuring instrument should comply with ISO/CIE 19476:2014 standard [4].

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Smartphones are mobile phones with computing capabilities and connectivity more advanced than regular ones. They appeared in the consumer market in the late 90s, but only gained popularity with the introduction of Apple's iPhone in 2007, which offered user-friendly features such as a touch screen interface and a virtual keyboard. According to Statista [5], an estimated total of 2.6 billion people will own a smartphone by 2017. In Portugal, the number of smartphone users increased 89% from 2013 to 2016 representing 68% (6.2 million) of the mobile phone owners [6]. These mobile devices have greatly evolved in the last few years and are no longer restricted to the traditional functions of making calls and texting. The integration of different types of sensors (hardware) and the development of many applications (software) turned them into interesting measurement instruments with huge potential in many different fields [7]. Their portability, ubiquity, permanent network connectivity and cost have attracted software developers to use embedded sensors for other purposes.

The aforementioned facts raised the following questions: (1) can a smartphone-based app be used for measuring light levels, and (2) in that case, will the accuracy be acceptable to substitute a dedicated and calibrated lux meter?

Within the occupational environment field, applications have been developed to assess risk factors such as noise [8], vibration [9] and light [8, 10, 11].

There are two different approaches to measure light with smartphone-based apps: some rely on one or both cameras while others use the embedded light sensor specifically designed to measure how bright the ambient light is and then adjust the display brightness automatically. Alternatively, there are small slip-on attachments for smartphones, such as Lumu exclusively for iOS phones and Luxi with a recent version available for both iOS and Android systems.

However, accurate measuring instruments are essential. While several studies on the accuracy of smartphone sound [7, 12–17] and whole-body vibration [18–20] measurement applications have been published, a single study [21] has been found to deal with the suitability of smartphones to measure illuminance. Goldschmidt [21] has tested seven mobile phones running on different operating systems (three iOS, three Android and one Windows) and three reference illuminances (100 lx, 500 lx and 1000 lx) were set on a horizontal platform to test seven apps (three iOS, three Android and one Windows). The author concluded that apps are not suitable for measuring illuminance and lead the user in the completely wrong direction.

Furthermore, measuring instruments need to be calibrated against known standards so their results can be trusted to have a universally accepted meaning. Although some of the apps used by Goldschmidt [21] were possible to calibrate, it was frequently not possible to set the value accurately.

This study sought to analyze the ability of smartphones to measure illuminance accurately and to assess the apps themselves and the platforms used to host them. Bearing this purpose in mind, a different set of mobile phones and applications were selected and different testing conditions were set.

2 Materials and Methods

2.1 Mobile Phones and Applications

The smartphones' sample was acquired among university students by asking them to volunteer their equipment for testing. It included nine smartphones: one running the Microsoft's Windows operating system, three were on the iOS Apple platform and five were Google's Android-based. This proportion follows 2016 world trend of consumers' preference in terms of mobile phones' operating system: Android (66.7%) and iOS (29.6%) were the leading platforms, well above Windows (1.4%) [22]. In Portugal, last year's 4th quarter figures were as follows: 81.7%, 17.9% and 0.3% respectively [23]. Table 1 presents a list of the tested phones' manufacturers and models and respective operating system.

Table 1. Smartphone's brand, model and operating system.

Operating system	Model
Android	Vodafone Ultra 6
Android	Samsung Galaxy A3 2015
Android	Samsung Galaxy A3 2016
Android	Samsung Galaxy SIII gti9300
Android	Huawei P8 Lite
iOS	iPhone 5S
iOS	iPhone 6S
iOS	iPhone 6 Plus
Windows	Nokia Lumia 520

Compliance with the following criteria was imperative for an application to be included in this study: being able to report illuminance values; being available at no cost; being highly scored by previous users. While Android and Windows based applications rely on the phone's light sensor to measure light levels, apps developers to iOS system have to resort to the camera.

Table 2 provides a full list of the 14 applications tested. Four Android-based apps allowed calibration to be accomplished. Although one app developed for the iOS platform mentioned to have this function, as it did not work properly the app was discarded. None of the Windows operating system apps presented this function.

2.2 Experimental Conditions and Procedures

All measurements took place in a black chamber to minimize light reflection and avoid the interference of other light sources than those being tested. Light color appearance of light sources, represented by Correlated Color Temperature (CCT) values expressed in kelvin, was considered a relevant variable in this study. Therefore, warm white, cool day white and natural white lights were obtained with two compact fluorescent lamps (2700 K and 6500 K) and one LED lamp (4000 K), respectively.

Table 2. List of the fourteen tested applications.

Application	Provider	Operating system	Calibration
Light Meter	Trajkovski Labs	Android	Yes
Easy Light Meter	Symbol Mobile	Android	Yes
Luximetro	Crunchy Bytebox	Android	Yes
Lux Meter	Waldau-Webdesign.de	Android	Yes
Light Meter Harmony	Classicharmony	Android	No
Physics Toolbox Sensor Suite	Vieyra Softwares	Android	No
Galactica	Flint Soft Ltd.	iOS	No
LUX Light Meter	Nipakul Buttua	iOS	No
Lux Light Meter - Pocket Illuminometer	Gang Li	iOS	No
myLuxRecorder	Satchidananda Panda	iOS	No
Lux-o-Meter	Martin Suchan	Windows	No
Exposure	MCNEXT	Windows	No
Light Gauge	LAT	Windows	No
Perfect Tools	Perfect Thumb	Windows	No

Different illuminance levels were achieved with each light source by changing the distance between the lamp and the platform where smartphones and the dedicated lux meter were placed to accomplish the measurements. Tests were completed at 300 lx, 500 lx, 750 lx and 1000 lx illuminance levels.

The order of CCT was randomized within each mobile device and the orders of illuminance level and app were randomized within each CCT.

Before each trial, the illuminance level was measured with a Hagner digital lux meter EC1-X, with an accuracy level higher than ±3%. These were considered the gold standard readings.

The lux meter detector and the smartphones' light sensor/front camera were placed axially below the luminaire in the middle of a horizontal platformat 70 cm high.

Whenever applications required calibration, the process was completed with a 100 lx illuminance level, before the tests took place.

2.3 Data Analysis

Data analysis was accomplished with SPSS software (version 24).

The relative paired differences between gold standard illuminance measurements and tests (apps) were computed using Eq. 1.

$$\text{Relative difference} = \left[\left(E_{app} - E_{lux}\right) / E_{lux}\right] \times 100\,. \tag{1}$$

Where:

E_{app} are the application readings (lx);
E_{lux} are the values obtained with the dedicated lux meter (lx).

Therefore, a relative difference of zero would indicate perfect agreement between the app and the actual illuminance value. The larger the absolute value of the relative difference, the poorer the device/app accuracy.

Standard boxplot analysis was used to assess the variability in the relative differences across applications and phone models. Descriptive statistics allowed determining operating system, application and phone performance.

Additionally, we performed Krushkal-Wallis and Mann-Whitney tests to assess the difference in deviation values associated to each platform (Android, iOS and Windows), across apps and smartphone models. A significance level of 0.05 was adopted as a criterion to reject the null hypothesis.

3 Results and Discussion

Figure 1 presents a scatterplot comparing illuminance values measured using mobile devices with readings of the dedicated lux meter at pre-specified reference conditions: 300 lx, 500 lx, 750 lx and 1000 lx. It is possible to observe the extent of variation in measured illuminance levels (VApp). Moreover, the higher the illuminance reference value, the larger the dispersion of the measured values.

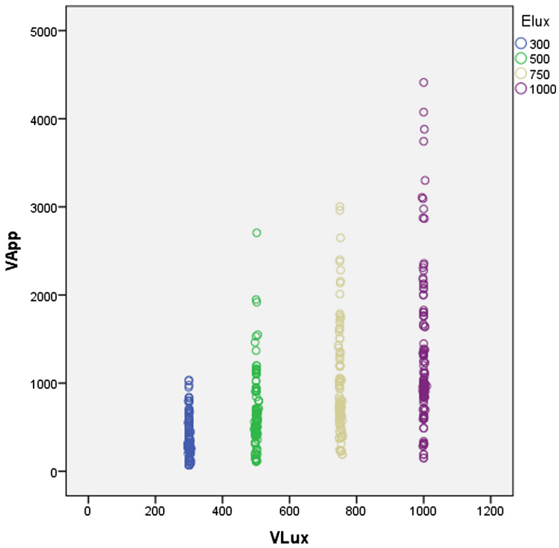

Fig. 1. Comparison between measured illuminance values (VApp) using smartphones with dedicated lux meter readings (VLux).

Table 3. Descriptive analysis showing testing results by illuminance reference condition in terms of relative differences of illuminance.

E (lx)	N	Mean	Min	Max	SD	SE
300	138	24.26	−77.67	244.67	70.71	6.02
500	138	26.81	−78.00	439.04	77.37	6.59
750	138	23.71	−74.77	300.40	73.39	6.25
1000	138	24.89	−84.90	341.20	79.78	6.79

Table 3 shows global descriptive statistics of the relative difference between the measured values using smartphones and the gold standard values. The deviations from the gold standard illuminance values were extremely high and smartphones' accuracy was much poorer than that found by Goldschmidt [21].

While the lowest measurements were nearly 85% below the reference value of 1000 lx, the highest reading was 439% above the 500 lx level. These results indicate that smartphones do not measure illuminance as accurately as a dedicated lux meter at the pre-established illuminance levels.

3.1 Operating System

The analysis of the relationship between measurement accuracy and the operating system revealed that there are statistical significant differences among mean values of the relative differences of illuminance (χ^2 = 138.36; $p < 0.001$). Turning our attention to the effect of the illuminance reference conditions (Table 4) it can be seen that different platforms present significantly different accuracy levels. While iOS platform underestimates illuminance levels systematically, both Android and Windows operating systems over measure the true illuminance level.

Table 4. Relationship between measurement accuracy and phone operating system at each pre-established illuminance.

E (lx)	Platform	N	Mean	SD	SE	χ^2	p-value
300	Android	90	35.82	66.87	7.05	28.08	<0.001
	iOS	36	−12.96	77.72	12.95		
	Windows	12	49.19	23.74	6.85		
500	Android	90	42.02	82.17	8.66	27.58	<0.001
	iOS	36	−19.30	55.62	9.27		
	Windows	12	51.01	24.32	7.02		
750	Android	90	38.37	76.01	8.01	40.79	<0.001
	iOS	36	−21.39	58.10	9.68		
	Windows	12	49.06	21.77	6.28		
1000	Android	90	42.03	82.73	8.72	41.56	<0.001
	iOS	36	−26.28	60.73	10.12		
	Windows	12	49.86	22.45	6.48		

Table 5. Relationship between measurement accuracy and phone operating system at each pre-established CCT.

CCT (K)	Platform	N	Mean	SD	SE	χ^2	p-value
2700	Android	128	54.15	73.02	6.67	99.768	<0.001
	iOS	48	−54.44	20.55	2.96		
	Windows	16	39.86	5.58	1.39		
4000	Android	128	13.07	37.38	3.41	55.30	<0.001
	iOS	48	−27.68	65.40	9.44		
	Windows	16	29.64	2.36	0.59		
6500	Android	128	51.46	100.30	9.16	16.40	<0.001
	iOS	48	22.17	65.92	9.51		
	Windows	16	79.82	5.51	1.35		

Table 5 shows that statistically significant differences were also found among the operating systems' performance in terms of illuminance measurement accuracy at each CCT reference conditions.

3.2 Applications

When examining the relationship between app and measurement accuracy, boxplots in Fig. 2 show a visual breakdown of the distribution of the relative difference between gold standard readings and measured data by application.

Android-based apps presenting calibration functions (left-hand side of Fig. 2a) revealed significantly lower mean deviations from the reference values than those with no calibration possibilities (χ^2 = 23.30, p < 0.001). Nevertheless, best mean relative difference was 31.1% (Light meter app/Borce Trajkovski) whereas the worst was 50.8% for the Physics Toolbox Light Meter app. The fact that some apps have calibration function does not necessarily mean it will be set accurately and it will render an accurate measure.

As a rule, all iOS applications displayed values below the reference levels (relative difference median values were negative) and presented statistically significant different performances (χ^2 = 21.01, p < 0.001). On the contrary, Windows-based apps did not present statistically significant differences (χ^2 = 0.40; p = 0.94) in terms of accuracy but displayed values well above the reference ones.

Galactica was the only app running on iOS we were able to find to match those previously tested by Goldschmidt [21]. Apps are added and removed from app stores on a daily basis and features and updates occur regularly.

3.3 Smartphones

The boxplot in Fig. 3 shows that, regardless of the operating system, phones present different accuracy levels when measuring illuminance (χ^2 = 250.19, p < 0.001). The best mean relative differences results were registered for Android based phones:

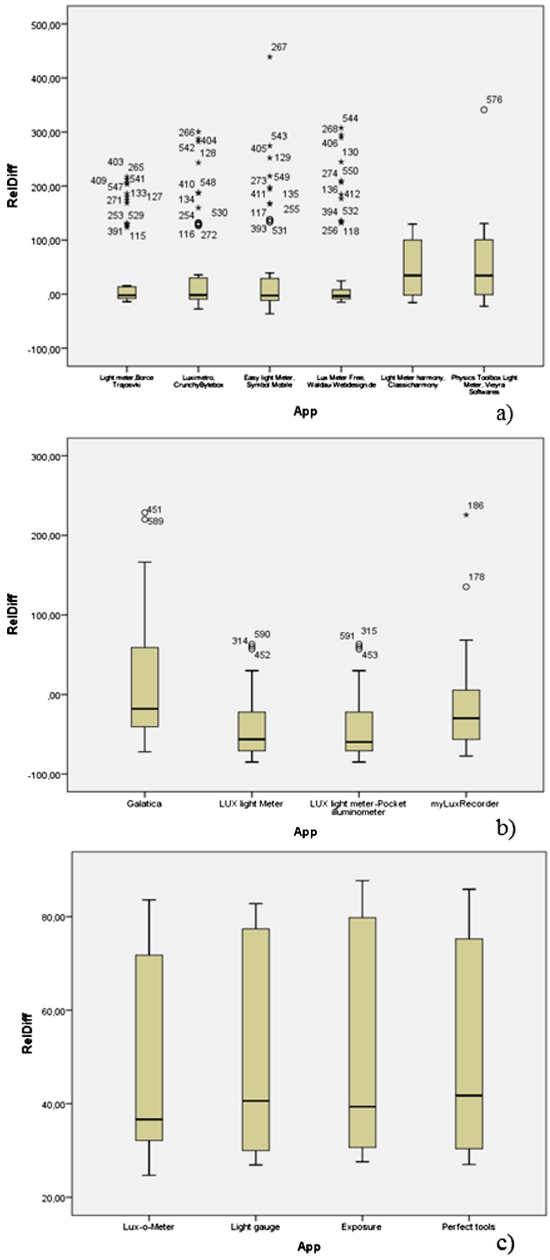

Fig. 2. Boxplot showing data distribution of relative difference between measured and reference values by application: (a) Android; (b) iOS; (c) Windows.

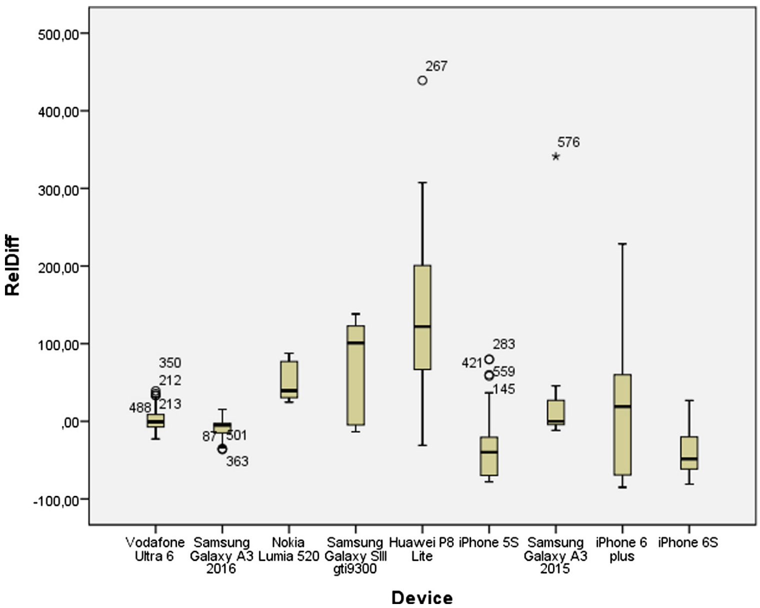

Fig. 3. Boxplot showing data distribution of relative difference between measured and reference values by smartphone.

Vodafone Ultra 6 (2.27%), Samsung Galaxy A3 2016 (−8.53%). Still these are far from being accurate as values ranges were 61.87 and 51.75, respectively. Turning to the iOS platform, iPhone models 5S and 6S displayed illuminance values 34% and 41%, respectively, lower than those of the lux meter while model 6 Plus readings were 15% higher. The single tested Windows-based phone over estimated illuminance levels repeatedly (mean relative difference of 50%).

Another interesting result shows that when using the same phone/app combination across different illuminance levels, the values displayed by the app deviate differently from the reference value. As an example within the iOS platform, for the iPhone 6 Plus/Galactica app combination, mean deviation values were 95.2%, 49.3%, 77.5% and 41.5% for the pre-specified illuminance values of 300 lx, 500 lx, 750 lx and 1000 lx, respectively. This same phenomenon was observed when the same phone/app combination measured illuminance levels across different CCT values. Illustrating for the Android operating system, when Huawei P8 Lite phone uses Light Meter app provided by Borce Trajkovski, mean relative difference between app reading and the reference level ranged from 183%, at 2700 K, to −9.1%, at 4000 K, and up to 204% at 6500 K.

These last results mean that a hardware/software combination does not present a stable response to illuminance variations nor light sources presenting different color appearances. Goldschmidt [21] invokes two main reasons for this abnormal behavior of smartphone/app combination:

(a) Smartphone embedded light sensors and cameras do not evaluate incident radiation according to the brightness sensitivity curve of the human eye in daylight like dedicated lux meter do;
(b) The angle of incidence is not taken into consideration by means of a weighting of the incident radiation.

Within the Occupational Safety and Health (OSH) scope, visual comfort and performance, safety and health are dependent on adequate illuminance levels. Therefore, using smartphone/app combinations to measure it may endanger workers' health and safety.

4 Conclusions

Illuminance level apps' incorporation in smartphones was thought as a viable tool for quick, cheap, convenient and versatile light measurement. Unfortunately only one study regarding the accuracy and the utility of these mobile phone apps was found [21]. Compared to it, our study includes different phones and apps comprising 552 tests. Four pre-specified illuminance levels were created with 3-different CCT light sources.

Smartphones suffer from accuracy limitations for estimating illuminance levels. The accuracy of illuminance measurement apps varied extensively relative to pre-specified reference levels and CCT values. There was no definite or predictable pattern to either lower or higher readings for the mobile apps compared to the lux meter: smartphones displayed higher readings in some cases and lower values in others. Therefore, it is not smart to use them to measure illuminance levels for OSH purposes as reporting incorrect values have serious implications from an occupational perspective.

This study has several limitations, mainly due to the small amount of devices tested but students owning phones of other makes and models have recently volunteered their equipment for further testing. Plus, only free apps have been considered for testing and we are aware that some paid versions may perform differently.

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Analysis of Competencies for Decision Crisis Management in Actions Under Progressive Stress: A Simulated Case

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Abstract. Skill development precariousness of disaster security management induces an ungoverned society in emergency situations. It is noted a gap in leadership competence in critical scenarios, with a demand for leaders with profiles focused on crisis management. The present work develops a discussion, to propose a crisis management training model. In this simulated model, it is understood that it is possible to identify a risk scenario evolution, such as a public building fire, as well as to evaluate the operative group's ability to cope with crisis, in a leadership role or in an accident course. This work develops a training model for leaders and performs a way of monitoring leaders' performance, according to which corresponds to procedures that are considered ideas and the presented result at the end of the simulation, an indication of increased competences of more assertive actions. From the training protocol implementation, it is expected society will cohabitate in an improved comfort position, where leaders are prepared to act in emergencies, in a relationship of cognitive knowledge and emotional balance, for crisis management, in progressive stress stages as well as in mass disasters.

Keywords: Fire · Crisis management · Contingency · Training – competence · Leadership

1 Introduction

The accident is an event due to an environment of uncertainty, a chain of failures, where it is necessary to assess the risk of its occurrence. The precariousness of skills development in disaster management is a perceived gap when the emergency situation sets in. It's observed that there is a lack of leaders with appropriate skills for critical scenarios, that is, the profiles of current leaders do not always meet the demands of crisis management.

The appropriate behavior for decision making, in this situation, requires a multiprofessional discussion, of the Manager, in the selection of professionals with decision-making powers, and those who take care of the stability of the psychological functions.

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Observing that the behavior of the person changes, according to the level of stress, to which it is submitted.

These functions may interfere with the leaders' procedures, in the face of an emergency scenario, that is, in contingency actions in the presence of progressive stress. It is a technique that aims to be suitable for simulation training with the objective of mobilizing participants to immerse themselves in an imaginary scenario with scenes of crisis that evolve in a degree of stress, allowing the participants to express behaviors that are reported and discussed, with the objective. To place the emergency situation closer to reality in the training environment and to provide the condition for developing a mental map that assists in more assertive decisions when confronting a crisis [2].

From this technique, other contents for simulated training are elaborated, which contemplate the presented decision making gaps, found after evaluation of the behavior of the participants who performed the simulation in situation of progressive stress. The responses to the emergencies reported allow for new moments of learning and development of competencies for decisions in emergency actions.

His explains the occurrence of progressive stress in a real-life accident scenario, when scenes of the crisis occur in Industry (fires, explosions), social accidents (terrorist attacks, collective exterminations), climate change (natural disasters), when Contingency responses and mitigation of damages are required.

Stress has the capacity to provoke reactions that can intervene positively or generate a lack of control of the operating group. In order to do so, it is expected that a leadership will be assumed with the knowledge and ability to maintain group cohesion, determine the assertive actions for the emergency and contain individual reactions that can increase the risks in a position of convergence with the accident already installed. The volume of an explosion, the fire, extensive smoke, uncontrolled staff, mutilation scenarios and loss of lives, are confronted by the need for emotional control of the team and its leadership, for the assertive response to the emergency. The different extreme of the expected patterns, provoke strangeness and imbalance generating the loss of perception of possible strategies to reduce the crisis, and admitting the existence of the extreme can bring a better behavior in the emergency actions [3, 9].

The perception, attention and memory are psychological functions and must remain active, within the dynamics of the individual in the execution of his task. Thus, simulation trainings with serial stimuli in scenarios of exhaustive crisis, can boost contingency actions in emergency. The competence to deal with crises can be developed from the simulated ones where the reason and the action by impulse need to live for a better route of decision-making.

Carvalho [4, p. 32] discusses the transformation of the knowledge acquired in training and the professional experience of the worker, in mental maps as a way of developing skills and thus, it is understood that decision-making more assertively in that accident situation and worker's expertise.

The perception of rules of behavior enables the development of competencies. The observation and experience of real events indicate which the appropriate attitudes to be taken. Thus, according to the group, one can infer about the existence of ideal procedures for the treatment of the crisis. Thus, according to the group, one can infer about the existence of ideal procedures for the treatment of the crisis.

The need to reproduce the behavior in procedure and this in training indicates the technique of operating groups as recommended. The phases of the accident are translated into training, leading the group to a positive safety performance, procedures are required that can translate the training phases and their contents to the positive performance of the team's safety.

It is worth emphasizing that the worker needs the motivation to perform technical trainings, and to put them into practice, it is not enough, therefore, to participate in the training without the commitment that the event, and not to react properly, using the learning when necessary.

To do so, it's understood that motivating an individual in the workplace is not a simple task. It requires skill and development of methodologies that provide, in addition to technical and practical knowledge, stimulate the commitment of the responsibility of preserving a safe environment, especially in the face of an accident scenario. According to Ávila and Bittencourt [1], different cultures can also trigger varied behaviors, differentiated understandings, and consequently affect the attitudes of the leadership and of its work team. Class the diversities explains the need to expand the training methodologies that best fit those facing an emergency. In these situations, it is perceived that dealing with situations of chaos simulation, repercussions on the most appropriate behavior to deal with the real moment of the accident.

The elaboration of a mental map, is a methodological strategy, and as Galante [6] explains, the strategy of interpretation and mental formation of ideas, knowledge and appreciation of the movements of an environment in crisis, provides answers that can better meet the need of the Accident and its consequences. Ávila [1], explains that exercise when it presents a high degree of tension, the stress limit of the group is observed and discussed. From this experience, it can be observed in the situation of an accident, the repercussion of better decisions, once the scenario presented during the simulation, had the ability to promote progressive stress, arrive at the evaluation of behavior in the responses in crisis situations.

To that end, Pichon-Riviere [8, p. 91] discusses a method for developing group tasks, with results and considerations of an action research carried out for operative research, where decision-making is based on a certain logic. In the dynamics of Pichon-Riviere [8] we perceive points in common to a certain problem studied, followed by the analysis of possible answers, without intervention of new elements, thus seeking a solution with what is available at the moment this group technique, the coordinator, specialized in the area of crisis management, is responsible for performing the simulation, with the function of developing the activity with mastery of technical and practical knowledge, communication and operability. There is a clear need to involve the participants in a journey around the construction of an imaginary around a crisis [8, p. 92].

Among the stages of the didactics applied by Pichon-Riviere [8, p. 93] in the experience called the Rosary Experience, the evaluation of behavioral development, individual and group knowledge, stands out.

This group technique brings to the discussion of the analysis of ideology, defined as a system of ideas and deliberations, when the man in possession of this understanding, makes possible a better direction for his decisions.

The elaboration of a cognitive map for an emergency, describes ideas, feelings, values and attitudes that reveal means, actions and alternatives for important decisions. The cognitive map technique is a modeling, which adapts to occurrences that predominate qualitative descriptions.

It is important to understand the practice of building the cognitive map for decision-making, when the leadership or group is questioned, the relevance of the situation experienced, the involvement and responsibility in the face of the problem, and what response should be demand in the crisis. These questions, which after analysis of the answers, are revealed as important factors in the actions of emergencies.

Knowledge and learning can be observed in the evaluation of the performance of a professional, in his area of technical domain. And skill, indicator of a person's ability to perform a task, and maintain self-control, which leads to emotional balance, even under stress.

When the worker composes mental models, the knowledge derived from training and professional experience, in general, the effectiveness of the development of competencies for the execution of successful tasks in the prevention, during the work routine, as in the mitigation of an accident [4].

It's hoped in this context that leaders and groups express their competencies to streamline operational processes, as well as share with the group, through dialogic communication, the development of the tactical and technical decision-making tasks necessary for contingency actions.

This article discusses a simulation model for monitoring crisis management through the development of competencies in contingency actions, with characteristics of emotional control, knowledge and skills Accompanied by scenarios with special effects that lead to the participants, in the proximity of a situation A crisis, and its consequences, motivated by the approach of facts associated with the manifestations of progressive stress, contained in the simulated exercise.

2 Competency Development

According to Mathisen and Bergh, the lack of perceived absence of competencies in the learning process is attributed in the present study to the behavior of leaders for contingency actions. Of leadership, including reinforcement of the knowledge of the task in safety, the insertion of work psychology for follow-up, measurement of the level of stress and the capacity to respond to emergency situations.

Knowledge of the organization's policy needs to be presented to the new contractor. As for the competence required for the performance of daily activities, it is linked to the process unit and final product technology [3].

The way to present scenarios of risk situations, is the first opportunity to insert the new contractors, the actions of preparation for responses to emergencies. Integration in the context of security represents the differential of a company, in demonstrating to the new employee, the security policy in the daily routines of the company.

The maintenance of the emotional balance depends on the quality of the interpersonal relationships and is preponderant for the success of the actions in emergency situation.

This is a skill demanded for the team that acts in the emergency brigades. The contingency of accidents, requires the decisions and attitudes of the leadership and its team to mitigate the damages caused by the accident. Thus, behavior to treat emergencies is based on the emotional control of the leader in front of the group.

The selection of candidates with a leadership profile and technical knowledge, and the company's policy of promoting continuous training are fundamental to the development of the capacity of a professional who is hired, as qualified to lead a group.

Avila [3] points out that competence is not always established for the person to exercise his role of leader, but it is possible to develop the professional through training, construction of new concepts and work in fieldwork that develop skills and competencies for crisis management in emergencies in a progressive stress environment.

The skills to deal with the crisis not only in leadership roles. This knowledge should be part of the working group in all functions as values to be internalized in the facilities of risk. The group that performs must understand and practice the perception of the beginning of crisis so that the group acts in the right time.

Vazirani points out that personal characteristics, as well as motivation, are non-measurable competencies proper to the individual's behavior. These skills require maturity, flexibility, cooperation, autonomy and independence to perform tasks.

Thus, the simulation strategy can be applied and validated statistically from the observation of behavior types, leadership styles, the organization of writing and the quality of the discourse of the actors acting in the simulation. The events in the dynamics must be interpreted making it possible to perceive the emergents of that group and how to reduce the risk of installing the crisis situation. The observer, responsible for the notes in the simulated training, perceives the actions and reactions during the dynamics. This methodological procedure indicates the rules, biases, and cognitive gaps that in the process of continuous learning feed the next action research.

3 Method

Table simulation is the technique that makes the research possible. It is intended to observe the behavior of the participants and the discussion of the practice, which becomes more "alive" when images are presented that resemble the environment of the accident. Images, noises, gestures indicating the existence of panic after a series of events that lead to accidents. The collection of data through the observation of the dynamic of progressive stress elaborates a set of information that when treated bring results. These preliminary results are presented to be evaluated as to the behavioral possibilities that increase the likelihood of the disaster. Therefore, this is an exploratory and descriptive scientific methodology, considering the hypothetical - deductive method. The method is based on the perception of a knowledge gap, about which it formulates hypotheses, and by the process of deductive inference, tests the prediction of the occurrence of phenomena covered by the hypothesis.

This exploratory method makes it possible to observe the environment and its components to understand the validity of the proposal and its variables, to improve the technique, in the face of the favorable and negative critical observations generated by the simulated participants at the end of the event.

The fire scenarios evolved to raise the participants' stress level, under the observer's notes, and shared with the actions described by the groups. The observer describes speeches, dialogues, movements and expressions that determine the actions performed for each presented scenario. It should be point that the presented scenario gradually exposes situations that increase the tension of the participants. The reduction of the response time, required by the activity coordinator, is a strategy to increase the agility of the simulation contingency actions. The site of the accident was chosen as a public building consisting of 10 (ten) floors, with classrooms, library, research laboratories, cafeteria, administrative rooms, auditoriums and atelier.

Participated in the study, 10 (ten) people who circulate frequently in the building, separated into 2 (two) groups. To conduct the simulation, a crisis response specialist coordinated the event. The observer, with knowledge in crisis management, occupied the position for notes of the occurrences of the simulation, and the groups chose a rapporteur. The annotations made by the groups, following the coordinator's instructions, were delivered and discussed at the end of the year.

In order to construct the scenarios, in advance, the coordinator of the simulation carried out a risk analysis in the building, to subsidize the elaboration of the scenes that specifically reflected the possible challenges and contingency responses, which the group was subjected to, in the imaginary confrontation of the crisis.

The dynamics presented in this case study was composed of 4 (four) phases with presentation of the scenarios. After the organization of the participants, separated by professions (Lawyer, Engineers, Economist, Administrator - researchers, masters and doctoral students) and positioning of the observer, the coordinator of the simulation requested concentration, attention and immersion in the activity, so that the scenarios were incorporated into the environment.

A room with low light, space used to perform the simulated table.

For the demonstration of the scenario, it was informed that in the Building, there was a welcome event for the new students, with the presence of teachers, employees and relatives, including children and the elderly. This event was held in an auditorium with the participation of approximately 320 people.

Scenario 01, is presented verbally, with image and sound. A loud crash echoes in the simulated environment. The bang, according to the coordinator, causes vibration of the structures and oscillation of the electric energy, leaving without lighting for some seconds. Then, according to the specialist and coordinator of the simulation, a breakout occurs and the room in this case study also remains for seconds with the lights off. Therefore, it is observed that the groups mobilize in the discussions, dialogue, express themselves and describe attitudes, feelings and possibilities for actions before the scene, in a previously stipulated time of 15 min.

Scenario 02, the coordinator aloud, and to the screams of dread of a woman, warns that people are running in panic in the corridors, guests have escaped from the auditorium and that 08(eight) people are in the elevator. Smoke is already circulating in the building and flames are seen through the windows. Panic installed. It is known that the beginning of the fire occurred in the cafeteria, on the 4th floor.

At this moment, it is noticed among the participants, greater mobilization and discussions. Participation actually happens, considering that the climate generated in the environment, and the possibility of a fire event being possible to occur outside the imaginary, leaves the participants of the simulation tenser. In 5 min the report is finished.

The Scenario 03, it is reported that some of the parents went out in search of their children, who went to the Cantina. During the trip, they noticed that there were many young people with extensive burns of 1st, 2nd and 3rd degrees, fallen, with cardiopulmonary arrest, in the main corridor of the building. This presentation is given in a high tone of voice and with the objective of generating the progressive stress, proposed in the simulation of the case study. Again, just 5 min to describe the actions in response to the crisis. For the presentation of the last phase, Scenario 04, is exposed the image of the young people who died burned, intoxicated and trampled, in the fire of Boite Kiss, in the city of Santa Maria, in Rio Grande do Sul. Fire in the Joelma building, in the city of São Paulo, which, although more than 40 years old, are strong and shocking.

Faced with the lack of passive and active protection of the building, of this simulation, the smoke and the flames took up a large proportion, on the whole 4th and 5th floor, it moves towards the 6th floor, at a speed that surprised everyone. Faced with the panic, some of the guests, unobserved, climbed to the 8th floor in an attempt to rescue. In a haughty voice, the coordinator places himself in the group, demanding an active position from each group, that is, the coordinator explores tension behaviors in the groups. This is the moment we want to link the real accident of the Joel building, to the scenario of study, which determines the approximation of the imaginary and reality. In this context, it can be seen that the participants of the simulation reacted with indignation at the difficulty in developing decision-making actions in the face of progressive stress scenarios, in a demonstration of inability to respond to emergency actions.

Communication is emphasized as a tool to follow the safety culture, in the space that one wishes to promote knowledge and experience in an unexpected accident. In this study, communication has fundamental participation in the dynamics of the simulation, built by speeches, images, expressions and media. Discussing the body positioning of the participants in the simulation exercise can be a response variable of decision-making behavior when compared to exercises performed with participants in comfort zone position, supported sitting in the chairs of the simulation room. It can be seen in exercises carried out, according to the experience of the specialist and coordinator of the simulation, that the standing position can influence the behavior of greater immersion in the scenarios and thus generate other stimuli that can enable responses to emergencies different from those Demonstrated in participants who perform the activity, sitting in the chairs of the simulation salt.

The hypothesis of the possibility of occurrence of different behaviors for response in the simulated table training, performed when the participants are positioned, standing around a market, with an illustration of the scenarios, can be tried, considering the observation of the expert and instructor of disaster simulations, responsible in this simulated case study, for the coordination of the experiment. For the analysis of the development of the simulation and performance of the groups, the material produced and the annotated observations were described in a table. Afterwards, the products were analyzed and the analysis was performed, for a qualitative discussion of the results achieved in this study. Content analysis, a qualitative research technique, usually infers the researcher, the analysis of the reports based on his theoretical and practical knowledge guided by his experience, intuition, competence, versatility [5, 7].

4 Result

O Group A reported on a sequence of ideas for crisis management, asking for action in a comprehensive and managerial way, showing a greater degree of decision-making than Group B. It was observed in a preliminary analysis that there was in Group B, A leadership with industry safety culture expertise.

Group B shows a sequence of ideas, with predominance of emotional decisions. Some comments are not appropriate, as an account of the technique used in the management of firefighting and rescue. What can be understood by the professional routine of the participants of the simulation. In the two groups, professionals from different areas participated, most of them Engineers, Lawyer, Administrator and Economist.

The sequence of stimuli to provide the participants with progressive stress was enough to promote internal anxiety in the search for a solution to the exposed scenarios. However, it is noticed that there was no complete immersion of the participants, a relevant factor for the accomplishment of a table simulation with the objective of expressive responses and development of leadership skills.

Given the reports and observations, the simulated repetition with characteristics of this case study, is considered strategic for the formation of a mental map. In this context, responses to accidents can happen more assertively, with the possibility of emotional control, in a real situation.

The following hypothesis is discussed: Should activities developed in the standing posture promote a better dynamics in decision making? What about the sitting position, it is understood that the participants of the simulation remain in a zone of comfort (inertia), influences in decisions with characteristics of planning and logistics of response to the accident? In this activity, the groups were seated, around the other, in an armchair, in a posture, traditionally school.

5 Conclusion

A discussion, to propose a training model in crisis management. In this simulated model, it is understood that it is possible to identify a risk scenario evolution, such as a public building fire, as well as assess the capacity of the operational group to deal with the crisis, in a leadership role or in a course of one accident. In the measurable assessment of all competencies, it is expected that leadership in decision-making in an emergency will contingency the event and thus, damages will be reduced, since they vary in impact, when there are deaths, social conflicts and economic losses. Acting assertively, will also preserve the company's image, removing a crisis, which results from an accident without contingency actions.

From the implementation of serial simulation training protocols, considering the inclusion of scenarios that present progressive stress sensations, society is expected to cohabit in an improved comfort position where leaders will be prepared to act in emergency situation. In a relationship of cognitive knowledge and emotional balance, for crisis management, in progressive stages of stress, as occurs in mass disasters.

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Investigation of Human's Evacuation Behavior in Multi-ethnics Jumping-off of China

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Abstract. It may encounter some severe problems when simulating a crowd evacuation using human's data collected from other countries. Thus, to ensure the safety of people in buildings, it becomes quite important to gather and analyze human's behavior and reaction in fire, with consideration of different culture backgrounds, behavior habits, different physiology and psychology characteristics et al. In this study, we designed questionnaires and analyzed human's individual characters, cognition degree of fire, sociological behaviors, as well as daily behavior characteristics statistically in multi-ethnics jumping-off of China. We bridged the gap between the human's characteristics (such as gender, age, education, job, environment cognition and toxic tolerance) and human's behavior in fire.

Keywords: Investigation study · Crowd evacuation · Human's behavior · Correlation analysis

1 Introduction

In the case of a fire, there are a large number of casualties due to the unreasonable layout of export settings, the crowd gathering, and the impact of panic [1]. According to statistics, 40 cases of devastating fires with more than 200 deaths happened in the last century. There is an urgent need to improve crowd management methods and design safety evacuation procedures. Thus in the past decades, more and more researchers from different research fields have been devoting to deepening our understanding of pedestrian and evacuation dynamics [2–6]. Pedestrian evacuation is composed of a series of complex behaviors, containing both evacuation movements and psychological reactions [7].

In order to make up for the shortcomings of theoretical and simulated research, it is necessary to conduct various investigations to obtain the law of psychological and

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behavioral changes in fires [8]. As early as the 1950 s, American scholar Bryan surveyed the behaviors of the fire in Arundel Park Hall in Brooklyn, Maryland, and wrote an investigation report, which started the early studies of human behavior in the fire [9]. However, strictly speaking, studies about fire accidents based on questionnaire surveys began in the 1970s. The British FRS (Fire Research Center) and the US NBS (US National Bureau of Standards, that is, the current US United States National Institute of Standards and Technology) carried out a series of researches on the behavior of people in the fire [10, 11]. Since then, the method of investigation has been widely applied, some scholars also used the investigation data to verify the evacuation model [12, 13]. However, we must note that the characteristics of human's behavior in evacuation will be very different under different regions and different cultural backgrounds [14]. A review of the literature suggests that studies of factors associated with human behaviors in the fire have so far focused predominantly on the central cities of Western and American countries. Although it is widely known that evacuation procedures in the jumping-off area are an important public safety issue, there has been very little work done in the jumping-off area, particularly, multi-ethnics jumping-off of China.

The investigation in Karamay, a multi-ethnics city in Xinjiang province of China, with 500 questionnaires was conducted. The statistical frequency of human's characteristics was obtained. With 395 available samples, 59.0% investigated subjects are male. Moreover, the ages, jobs, educations of samples are widely distributed, indicating that the investigated groups are representative of the local society. We also investigated the human's behavior (human's cognition degree of fire, sociological behaviors, and daily behavior characteristics) during an evacuation. Using Pearson test, 30 groups with p-values smaller than 0.05 were found to be related, linking the human's characteristics and human's evacuation behavior. Then a multi-correspondence analysis was conducted to analyze between these 30 related groups.

Based on statistical analysis of questionnaires, the study revealed some important and interesting findings. Firstly, an overwhelming majority of elder respondents has at least once fire experiences or public safety emergency drill at the time of the survey, so they are more familiar with fire-fighting equipment and tend to evacuate immediately after the fire alarm. Secondly, females' knowledge of fire safety and awareness of unsafe fire behaviors is relatively limited, and the majority of males tends to take a proactive actions when facing a fire, such as calling fire brigade, attempting to extinguish a fire, and trying to alert others. Thirdly, females are more likely to choose the nearest exist while males were more likely to choose the exit they which they are most familiar with. Fourthly, respondents with stronger toxic tolerance take the elevator in their busy daily life more often, and they tend to observe other people's reaction instead of evacuating immediately after the fire alarm. Lastly, herd behaviors that are documented elsewhere to be highly occurred in fire were found not to be obvious in this investigation.

2 Materials and Methods

2.1 Survey Design

Based on pedestrians' psychological and behavioral responses in building fires, factors that affect human's behavior and evacuation time were screened. The questionnaire included four parts: the individual information, the fire safety knowledge, the human's behaviors in fire and the human's lifestyle, accommodating a total of 27 topics. The design of the questionnaire is shown in Fig. 1.

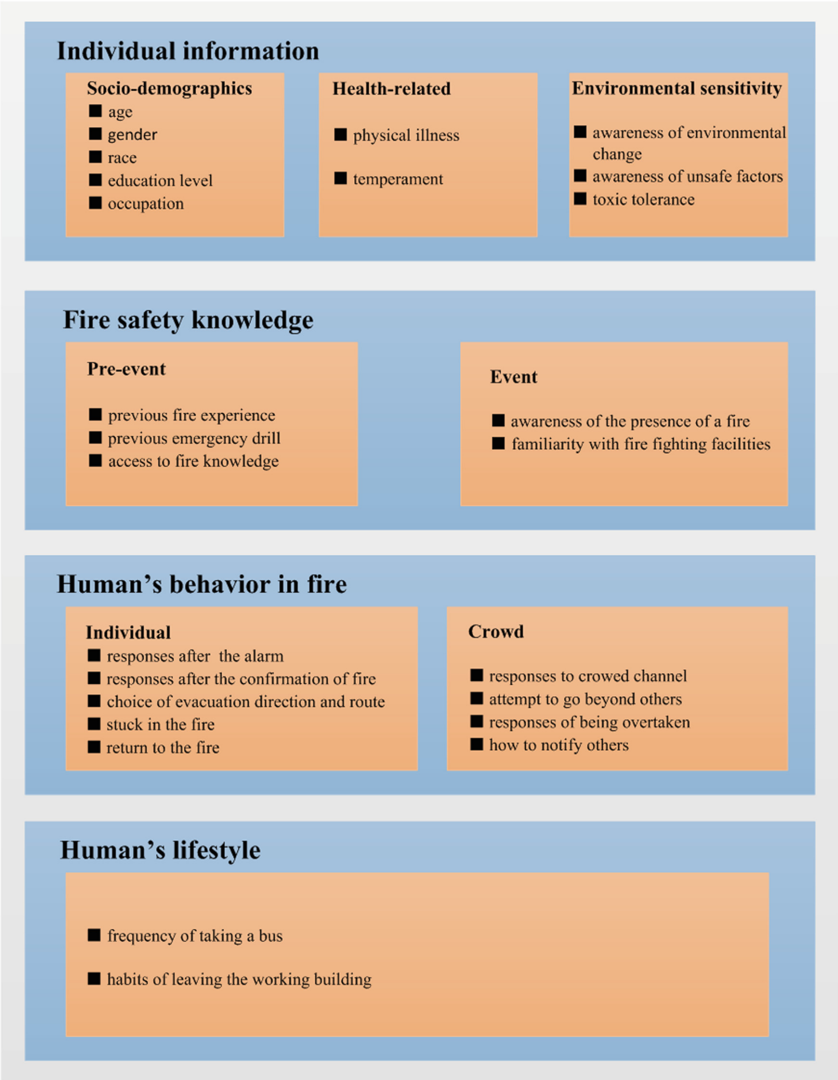

Fig. 1. Factors organized in the questionnaire

2.2 Survey Conducting

The investigation in Karamay, a multi-ethnics city in Xinjiang province of China, with a total of 500 questionnaires was conducted.

All personnel in the research group accepted comprehensive training before the survey, including research objectives, analytical ideas, methods and processes, quality requirements, access outlines and specific requirements in the implementation. Investigators should use the pre-prepared specifications to instruct participants to fill out the form. When filling out the questionnaire, a quiet answering environment was ensured. And investigators would inspect whether the filling methods conform with the requirements or not. It must be ensure that the answers are correct and complete, the handwriting is clear and the multiple questions are answered reasonably. For all questionnaires, the data should be reviewed before entering the database. The questionnaires were entered twice and then were subjected to logical checks and corrections. All recovered questionnaires were carefully preserved for future review.

Finally 436 questionnaires were recovered, and after excluding 41 nonconforming copies there were 395 valid samples.

3 Results

3.1 Individual Information

In this presentation, the individual information included 3 aspects: socio-demographics, health-related and environmental sensitivity. The specific findings are shown in Table 1.

With 361 available samples, 59.0% investigated subjects are male. Moreover, the ages, jobs, educations of samples are widely distributed, indicating that the investigated groups are representative of the local society.

The physical condition of participants was generally well. More than half of the participants had steady temperament and general sensitivity of the environmental changes. As for the toxic tolerance, 45.5% of the participants is tolerant to environmental toxic, and 45.8% of the participants did not have endurance to environmental toxic. Only 5.8% of the participants adapted well to environmental toxic.

3.2 Fire Safety Knowledge

Previous experience of a fire or public safety emergency drill has significant influence on pedestrians' behavior and psychological change under the conditions of fire. Those who have experienced fire and other emergencies will be more mentally prepared than those who have not experienced similar incidents. They can better control their own behavior and conduct more efficient evacuation. For example, those who have participated in safety training will have a stronger sense of self-protection and will take more reasonable action after recognizing that a fire has occurred, while those who have not experienced similar incidents can not calm thinking which will lead to some impulsive and blind action [15].

Table 1. Frequency distributions of individual information.

Individual information		Number	Percentage (%)
Gender (n = 385)	Male	227	59.0
	Female	158	41.0
Race (n = 380)	Han	168	44.2
	Minority	212	55.8
Age (n = 377)	<14	6	1.6
	14–20	46	6.0
	21–45	214	28.7
	46–55	97	25.8
	>55	14	3.7
Occupation (n = 385)	Company staff	264	68.6
	Self-employed	46	11.9
	Student	56	14.5
	Civil servant	7	1.8
	Unemployed	12	3.1
Education degree (n = 369)	Primary school	28	7.6
	High school	160	43.4
	College	141	38.2
	Bachelor degree	39	10.6
	Master degree	1	0.3
Physical conditions (n = 386)	Very healthy	244	63.2
	General	132	34.2
	Weak	8	2.1
	Others	2	0.5
Temperament (n = 380)	Cautious	102	26.8
	Steady	207	54.5
	Adventurous	23	6.1
	Others	48	12.6
Awareness of environmental change (n = 386)	Quick	145	37.6
	General	228	59.1
	Slow	8	2.1
	Others	5	1.3
Awareness of environmental change (n = 386)	Quick	192	49.7
	General	168	43.5
	Slow	11	2.9
	Others	15	3.8
Toxic tolerance (n = 378)	Strong	22	5.8
	General	172	45.5
	Weak	173	45.8
	Others	11	2.9

In this investigation, we focused on whether the participants have experienced fire and other incidents or participated in public safety drills. What's more, what did the participants know about the firefighting facilities and how could they recognize that a fire happens were also been considered, as shown in Table 2.

Table 2. Frequency distributions of fire safety knowledge.

Fire safety knowledge		Number	Percentage (%)
Previous fire experience (n = 220)	Yes	8	3.6
	Witnessed	54	24.5
	No	158	71.8
Previous emergency drill (n = 381)	Never	58	15.2
	Having some fire knowledge	115	30.2
	Having special training	140	36.7
	Experience fire drills	60	15.7
	Others	8	2.1
Familiarity with firefighting facilities (n = 375)	Very skilled	76	20.3
	Knowing nothing	14	3.7
	Having used once or twice	228	60.8
	See others used	57	15.2
Access to fire knowledge (n = 360)	School of company	117	32.5
	Lecture	50	13.9
	TV or newspaper	98	27.3
	Friends or neighbors	32	8.9
	Others	63	17.5
Awareness of the presence of a fire (n = 380)	Smoke	166	45.0
	Flame	106	28.7
	Noticed by others	42	11.4
	Alarm	55	14.9

3.3 Human's Behaviors in Fire

In this section, we investigated how the participants behaved in fire, including the individual behaviors and the relationship between the participant and other evacuees. As shown in Table 3, evacuation indicators provided a lot of help for participants. And people were willing to return to the fire for their companions (71.5%), but they would

Table 3. Frequency distributions of human's behavior in fire.

Human's behavior in fire		Number	Percentage (%)
Responses after the alarm (n = 380)	Asking other to confirm	100	26.3
	Running to the window or door	100	26.3
	Observing others' reaction	29	7.6
	Evacuating immediately	151	39.7
Choice of evacuation direction and route (n = 375)	According to distance	68	18.1
	According to familiarity	110	29.3
	Following the crowd	10	2.7
	Following the evacuation indicator	187	49.9
Return to the fire (n = 383)	Separated with companions	274	71.5
	Rescue property	56	14.6
	Help strangers	9	2.3
	Never	44	11.5
Responses to crowed channel (n = 385)	Squeezing through the crowd	16	4.2
	Waiting in line	23	6.0
	Follow the strong people	34	8.8
	Find other channels	312	81.0
Responses of being overtaken (n = 335)	Following him	94	28.1
	Completing with him	60	17.9
	Ignoring it	31	9.3
	Making way for him	150	44.8
When you want to overtake others (n = 385)	Moving around him	206	53.2
	Follow him	110	28.4
	Forcing him to speed up	36	9.3
	Others	35	9.0
How to notify others (n = 388)	Shouting loudly	324	83.3
	Only telling people close to me	29	7.5
	Only telling those who are heading to the dangerous exit	33	8.5
	Only telling the familiar person	2	0.5

not take risk for strangers (2.3%). Meanwhile, when conflicts happened, participants tented to find other channels (81.0%) or move around (53.2%), and they were happy to share information about new evacuation exits to any other one (83.3%). It means that most pedestrians were willing to cooperate with each other.

3.4 Human's Lifestyle

In this section, we investigated participants' habits in their daily life. Results are shown in Table 4.

Table 4. Frequency distributions of human's lifestyle.

Human's lifestyle		Number	Percentage (%)
Habits of leaving the working building (n = 386)	Elevator	151	39.1
	Stairs	73	18.9
	Both are the same	162	42.0
Frequency of taking a bus (n = 220)	Never	27	6.9
	Sometimes	213	54.2
	Always	148	37.7
	Other	5	1.3

4 Discussion

Using Pearson test, 30 groups with p-values smaller than 0.05 were found to be related, linking the human's characteristics and human's evacuation behavior. The results are shown in Table 4. Then a multi-correspondence analysis was conducted to analyze between these 30 related groups.

Based on statistical analysis of questionnaires, the study revealed some important and interesting findings. Firstly, an overwhelming majority of elder respondents has at least once fire experiences or public safety emergency drill at the time of the survey, so they are more familiar with fire-fighting equipment and tend to evacuate immediately after the fire alarm. Secondly, females' knowledge of fire safety and awareness of unsafe fire behaviors is relatively limited, and the majority of males tends to take a proactive actions when facing a fire, such as calling fire brigade, attempting to extinguish a fire, and trying to alert others. Thirdly, females are more likely to choose the nearest exist while males were more likely to choose the exit they which they are most familiar with. Fourthly, respondents with stronger toxic tolerance take the elevator in their busy daily life more often, and they tend to observe other people's reaction instead of evacuating immediately after the fire alarm. Lastly, herd behaviors that are documented elsewhere to be highly occurred in fire were found not to be obvious in this investigation.

Appendix: p-Values Between Evacuation Behaviors and Personal Characteristics

Personal characteristics	Evacuation behaviors							
	Fire drill	Fire experience	Evacuation facilities	Fire information	Route congestion	Crowded	Being overtaken	Facing disability
Part I								
Age	0.01	0.195	0.009	0.945	0.721	0.069	0.228	0.412
Gender	0.555	0.450	0.013	0.459	0.885	0.201	0.462	0.229
Occupation	0.009	0.000	0.002	0.118	0.170	0.445	0.135	0.146
Education level	0.384	0.090	0.226	0.564	0.202	0.340	0.764	0.615
Health-related	0.814	0.384	0.278	0.079	0.005	0.418	0.088	0.090
Temperament	0.813	0.511	0.726	0.092	0.237	0.681	0.011	0.250
Awareness of environment change	0.266	0.133	0.006	0.214	0.010	0.938	0.002	0.009
Toxic tolerance	0.167	0.000	0.270	0.578	0.179	0.003	0.024	0.305

Personal characteristics	Evacuation behaviors						
	Impacts	Announcement of fire	Announcement of route	Transportation pattern	First response	Escape direction	Likely response
Part II							
Age	0.699	0.013	0.000	0.323	0.046	0.062	0.988
Gender	0.525	0.027	0.181	0.108	0.405	0.695	0.868
Occupation	0.041	0.002	0.000	0.872	0.001	0.002	0.321
Education level	0.524	0.403	0.539	0.828	0.386	0.824	0.909
Health-related	0.213	0.125	0.001	0.048	0.188	0.001	0.699
Temperament	0.008	0.752	0.352	0.014	0.313	0.317	0.084
Awareness of environment change	0.115	0.060	0.126	0.003	0.156	0.070	0.757
Toxic tolerance	0.661	0.653	0.001	0.263	0.049	0.358	0.152

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Assessment of Human Factors Analysis and Classification System in Construction Accident Prevention

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Abstract. Majority of the incidents and accidents in complex high-risk systems that exist in the construction industry and other sectors have been attributed to unsafe acts of workers. The purpose of this paper is to asses Human Factors Analysis and Classification System (HFACS) in construction accident prevention. The study was conducted through the use of secondary data from journals, books and internet to achieve the objective of the study. The review of literature looked into details of different views from different scholars about HFACS framework in accidents investigations. It further highlighted on various sections or disciplines of accident occurrences in human performance within the construction. The findings from literature review showed that unsafe acts of a worker and unsafe working conditions are the two major causes of accident in the construction industry. The most significant factor in the cause of site accident in the construction industry is unsafe acts of a worker. The findings also show how the application of HFACS framework in the investigation of accident will lead to the identification of common trends. Further findings show that provision for the prevention of accident will be made based on past accident records to identify and prioritize where intervention is needed within the construction industry.

Keywords: Accident · Construction indusrty · HFACS · Prention · Unsafe acts

1 Introduction

The construction sector does not have an enviable record or reputation and its Health and Safety (H&S) compliance can be described as poor in comparison with other industries [1]. Eighty percent (80%) of all incidents and accidents in industries has been attributed to human error [2–4]. Construction workers may commit unsafe acts or cause existence of mechanical or physical hazards that will result in injury as indicated by the five dominoes model [5]. Unsafe acts are classified as either errors or violations as shown in Fig. 1 [6]. Errors are major contributor to accidents while violations are less common. Unsafe acts of workers has been rated high as compared to poor working conditions as the major contributors of accidents and injuries in the construction industry [7].

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Majority of accidents are due to human error and the accident can only be prevented if management provides conducive environment for the employees to work. Hosseinian and Torghabeh [5] argued that accident can be either caused by singular human error or a combination of them as immediate causes of accidents; the combination of violation and mistake is a very usual cause of accidents. James Reason's model of latent and active failures serves as a foundation for Human Factors Analysis Classification System, HFACS) [8]. In the current study human factors analysis and classification system (HFACS) taxonomy was used to assess how it may affect the understanding of human errors in construction sector. This paper began with the background of human factors analysis and classification system and human factors analysis and classification system framework. This is followed by unsafe acts of workers leading to accidents and preventive efforts towards elimination of accident.

2 Research Objectives

The study addresses the following questions:

1. How do Unsafe Acts of workers lead to accident?
2. How can Human Factors Analysis and Classification System (HFACS) framework be applied in accident investigation?

From a discussion based on the key works in the literature. What it means when HFACS framework is applied and what to achieve by applying it. The final part of the paper is devoted to a consideration of how accidents can be minimised in the construction industry by applying HFACS framework.

3 Design/Methodology

The research method adopted was literature study from various sources such as literature reviews of types of Human Factors Analysis Classification System (HFACS) frameworks in the investigation of accident. Studies relevant to HFACS frameworks were selected out of the numerous studies reviewed, through a rigorous process. Data from literature review was analyzed and used to explain how to implement human tools in the current study. Reduction in human error in the construction sector may contribute in minimizing the adverse effects on employees.

4 Literature Review

Errors in behaviour model are likely to be done by humans in different environmental conditions. However, humans are blamed just for their unsafe behaviour [5, 9]. Appropriate strategies can be put in place to handle any unsafe acts of workers if they know the causes behind the acts. The relationship between unsafe condition and unsafe act is a one-to-many interaction. Unsafe condition can lead to many hazards and unsafe acts of human [5, 10, 11]. Therefore, the need to protect workers from any hazard in the construction industry has become necessary due to its labour intensiveness.

The HFACS is a general human error framework originally developed and tested as a tool for investigating and analyzing the human causes of accidents [4]. HFACS, based upon Reason's model of human error in an organisational context, is currently the most widely used human factors accident analysis framework [8, 12]. It is a comprehensive human error framework that folded Reason's ideas into the applied setting and defined 19 causal categories within four levels of human failure [8, 12]. The HFACS is based on the "Swiss Cheese" model of human error [6] which looks at four levels of active errors and latent failures, including unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences [8, 12]. HFACS is a commonly utilized tool for investigating human contributions to construction accidents under a widespread evaluation scheme. The HFACS framework enables organizations to identify the breakdowns within the entire system that allow an accident to occur.

Several safety models have focused on human factor and proposed to analyze incidents and identify their causes [2, 13]. One such safety model is the HFACS. HFACS is a comprehensive accident investigation and analysis tool which focuses on the individual act preceding the accident and other contributing factors in the system [2, 14]. In depth examination of human error may contribute to accident reduction and increase safety of work. Researchers have used HFACS to investigate the causes of accidents in the construction sector [4, 12, 15] thereby reducing accident caused by human error. Several researchers [12, 13, 16] have shown the extended applicability of the HFACS to other types of industries for investigating accidents.

5 Background of Human Factors Analysis and Classification System (HFACS)

The HFACS is a broad human error framework developed by Dr Scott Shappell and Dr Doug Wiegmann. HFACS was originally used by the United States (US) Air Force to investigate and analyse human factors aspects of aviation. The HFACS is heavily based upon James Reason's Swiss Cheese Model [6, 12]. The HFACS system was originally developed as an evaluation framework to analyze and classify operator errors in naval aviation accidents and mishaps. Dambier and Hinkelbein [12, 17] have utilised the generic framework of the HFACS model intensively in aviation accidents investigations. The Human Factors Analysis and Classification System (HFACS) is a general human error framework. It was originally developed and tested as a tool for investigating and analyzing the human causes of accidents with applications to construction industry and other sectors [12].

The HFACS framework provides a tool to assist in the investigation process and target training and prevention efforts. Investigators are able to systematically identify active and latent failures within an organisation that culminated in an accident. The goal of HFACS is not to attribute blame but to understand the underlying causal factors that lead to an accident [12]. HFACS was cited by Dekker [13] as one of the most powerful tools for reconstructing human contributions to various types of accidents.

6 Human Factors Analysis and Classification System (HFACS) Framework

The general framework of the analytical HFACS mechanism for accident investigation process as illustrated in Fig. 1 has four main levels: Unsafe Acts - this includes errors and violations; Precondition for Unsafe Acts - includes environmental factors, condition of individuals, and personal factors; Unsafe Supervisions - includes inadequate supervision, inappropriate operation, failing to correct problems, and supervisory violations; and Organizational Influences- includes resource management, organizational climate and organizational processes. Any occurrence of adverse event can be prevented, if one of the failures leading to adverse event is corrected as it implies in the construction accident prevention [12]. The application of Human Factors Analysis and Classification System (HFACS) framework for accident investigation enables organizations to be able to identify the breakdowns within the entire system that will lead to an accident. The HFACS can also be used proactively by analyzing historical events to identify reoccurring trends in human performance and system deficiencies. Both of these methods if employed in the construction industry will allow the identification of weak areas and implement target and data-driven interventions which will ultimately reduce accident and injury rates. The HFACS provides a structure to review and analyze historical accident and safety data. By breaking down the human contribution to performance, it will enable the analyst to identify the underlying factors that are associated with an unsafe act. The HFACS framework may also be useful as a tool for guiding future accident investigations in the construction industry. It can be used to develop better accident databases, both of which would improve the overall quality and accessibility of human factors accident data [12].

Identification of common trends based on past accident records, will support the identification and prioritization of where intervention is needed within the construction industry. This implies past accident and safety data will be reviewed and analysed to give a clue to the identification of any failure before its occurrence. This will result in improved human performance and decreased accident and injury rates in the construction industry [12]. Prior to the implements any safety practices from another industry, a deep and thorough knowledge of its own safety practices is vital [19]. Li and Harris [20] opined that safety improvements should be focused on the start of organizational climate and organizational process - to achieve the optimal benefits from the implemented safety improvements as per construction industry.

7 Unsafe Acts of Workers Leading to Accidents

Accidents at work occur either due to unsafe worker acts and unsafe working conditions. Abdelhamid and Everett [7] asserted that unsafe act is the most significant factor in the cause of site accident in the construction industry. Unsafe acts have been identified by [7, 21] as follows:

i. Working without authority on the job can cause accidents since unauthorized workers may lack the necessary skills, or unfamiliar with the job process.

ii. Working at improper speeds, exceeding the prescribed speed limits, or unsafe speed actions could cause accidents, e.g. workers who handle objects quickly could slip and be injured.
iii. Incorrect use of tools and equipment, hand tools, power tools, and machinery can also cause accidents. For instance, workers who frequently climb or stand on rebars instead of using a ladder could fall down.
iv. Improper placing and stacking of objects and materials in dangerous locations can result in unpredicted accidents e.g. a worker could collide with such objects.
v. Improper lifting, handling, or moving of objects may cause serious back pains, e.g. workers who manually lift heavy objects without proper force-saving equipment.
vi. Failure to warn or to secure members out of danger is considered as an unsafe act since many accidents occur because workers' pay less attention to warning or securing co-workers who are working under conditions with high probability of accident occurrence.
vii. Using defective equipment and tools to work, e.g. a worker who uses a substandard ladder could fall and be injured.
viii. Annoyance and horseplay in the workplace such as young workers who play roughly around the workplace could encounter unexpected accidents.
ix. Ignoring to wear personal protective equipment (PPE) may increase chances of getting injured, e.g. workers without hardhats are more prone to getting head injuries from falling objects equipment could raise the chances of getting accidents, e.g. workers who remove guardrails could fall down.
x. Working in poor physical conditions such fatigue, stress, or drowsiness could also increase the likelihood of accidents.
xi. Leaving nails or other sharp objects protruding from timber may cause accidents as workers who do not wear safety shoes could step on these objects and be injured.
xii. Throwing or accidentally dropping objects from high levels could expose other workers to sustaining possible head injury.
xiii. Working with lack of concentration, such as workers talking while undertaking a job could cause distraction and result in an accident.
xiv. Working under the effects of alcohol and other drugs could increase workers' unawareness and cause serious accidents.
xv. Improper positioning of tasks can also result in accidents, e.g., workers on high levels could fall and be seriously injured.
xvi. Improper posture for tasks such as workers taking shortcuts by climbing or jumping from high levels instead of using ladders could result in serious injury.
xvii. Servicing equipment which is in operation, e.g. refuelling a machine without first turning off the engine could cause a severe accident.
xviii. Smoking, creating naked flame or sparks in areas where flammable materials are stored could cause explosions.

8 Preventive Efforts to Eliminate Occurrence of Accident

It is mandatory for all employers to provide their employees a work place which free from any health related problems as stipulated in the OHS Act of 1970. Since Occupational Safety and Health Administration (OSHA) enshrined the protection all employees by enforcing the standard: through the provision of adequate training and education for all its employees [22].

Protection of Employees from Unsafe Working Conditions. Under federal and state laws, employers must provide a safe workplace. The enforcement of the act and establishment of safety standards under the OHSA. The safety standards include provisions for the storage of hazardous chemicals, equipment maintenance, fire protection, and personnel protective equipment. OSHA is mandated to prove protection to workers from injuries, illnesses caused by unsafe health conditions in any working environment. In addition to this, OHSA must also be able to recognize any hazards within the work environment that may cause death or serious injury to employees.

Employers must abide by the safety standards within the working environment in order to protect their employees from any unsafe working condition by:

i. Providing a working environment that free from any health and safety hazards that may cause death or serious injury,
ii. Providing and placing a OSHA work safety notice in the working environment,
iii. Keeping update of a record of injuries, deaths, and exposure to hazardous material,
iv. Providing safety training to all its employees when desired,
v. Safety standards set by OSHA include provisions for the storage of hazardous chemicals, equipment maintenance, fire protection, and protective clothing [22].

Education and Training. Education and training programmes should play a significant role in enhancement of safety in construction. It is also important to increase safety awareness and change behaviour of employees [23]. Effective health and safety training can contribute to accident prevention in the construction industry. Therefore, the need for education and training of employees in all aspect of health and safety in the construction industry. Workers need to be aware of the hazards and risks at their workplaces in order to encourage them to work in a healthy environment and safety manner [24] because lack of training is a barrier. It is the duty of the employers to assess that the working environment is safe for workers. No work should be carried out by employees unless it has been confirmed that such environment has the structural integrity to support the safety of all workers. Tools and equipment to be used are also in good condition. Employees should determine that they are safe before the use of any tool or equipment on site [25].

9 Lessons Learned

The following are the lessons learnt from the application of HFACS framework in accident prevention:

i. The application of HFACS taxonomy will lead to the assessment of how it affects the understanding of human errors in construction sector. Since human errors has been idendified as the main cause of accident in the construction sector.
ii. The investigation process in the HFACS framework provides a tool that assist in the training and prevention efforts.
iii. The HFACS can be used proactively by analyzing historical events in the construction sector to identify reoccurring trends in human performance and system deficiencies.
iv. The use of OHS Act of 1970 as a preventive measure for construction sector accident minimization.

10 Conclusion

The purpose of this study was to examine human factors analysis and classification systems taxonomy in accident prevention in the construction sector. The review showed how human error has been attached to accident in the construction sector. Unsafe acts of workers was found to be the major contributing factor to accident. Proactive measures to analyze past accidents records was achieved through the application of HFACS framework. Occurrences of future accidents in human performance and any deficiency in the system will be realized through the application of HFAACS to provide appropriate preventive measures to be employed.

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Human Element as the Contributing Factor Towards Construction Accidents from the Perspective of Malaysian Residential Construction Industry

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Abstract. Malaysian construction industry is crucial in the development of the country towards becoming a developed nation. However, the positive growth of Malaysian construction industry is being affected with high fatality rate. There are four main elements contributing to occupational accidents in the industry comprising of immediate factor (human and worksite) and underlying factor (management and external). Human element is considered the most significant and obvious contributing factor towards occupational accidents in the construction industry. This element is formulated by the four sub-elements, human physical, experience, attitude and behavior. 13 residential projects comprising of seven high-rise and six low-rise projects were chosen in Penang, Malaysia. 135 and 13 respondents were selected for questionnaire survey and interview respectively. Attitude and behavior registered the highest mean average in human element. Comparison made between high-rise and low-rise projects respondents shown that there is no significant difference in the perspective of these two groups towards human element.

Keywords: Construction safety · Construction fatalities · Human element · Occupational accident · Safety management · Safety legislation

1 Introduction

Construction is a major industry in Malaysia and one of the economy sub-sectors in enhancing other major industries in Malaysia as well as impacting national economy [1]. It also plays an important role in socioeconomic growth through the development of infrastructures [2]. Housing industry is essential in Malaysia due to its significance towards fulfilling social and economic needs.

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Construction industry is known as a unique, complex and hazardous workplace [3–8]. Due to the nature of this industry, particular attention needs to be given to occupational safety and health (OSH) aspect. OSH problems in construction are a global issue that is rarely unique to a single country in this global market and occupational injuries and fatalities are still occurring at an alarming rate [9].

Causes of occupational accidents and illnesses in construction industry are separated into two main parts, the immediate causes and the underlying causes. A framework of causes leading to occupational accidents and illnesses in construction industry established from previous researches in this area. Human element is one part of the immediate causes that is relatively easy to be detected during investigation compare to the underlying causes. Approximately two third of the accidents that occurred in construction industry could be related to human element with action/behavior and workers capabilities as the main causes [10].

Human element as contributing factor towards occupational construction accidents have been widely studied around the world. However, this paper will discuss the human element issue towards construction accidents in the context of Malaysian residential construction industry. Safety factor adopted at national level differ from one country to another based on the standard practices for that specific country [11]. Different legislation, level of involvement from governmental organizations, safety culture and construction practices may influence the impact of human element in the context of Malaysia.

The main objective of this paper is to study the perception of local construction personnel in Malaysian residential construction industry regarding human element as contributing factor towards construction accidents. Specific objectives of this study are (i) to understand the contribution of human element towards occupational accidents in construction industry; (ii) to compare the perspective of respondents from high-rise and low-rise residential projects; and (iii) to analyze the correlation of human element towards four major types of occupational accidents in construction industry.

2 Fatalities in Malaysian Construction Industry

Construction industry endures high fatalities due to the high risks of accidents in the workplace globally including Malaysia. Fatalities in construction industry need to be controlled to curb the losses in terms of labor, properties and national development [12].

Table 1 illustrates the number of fatalities cases that were investigated by Malaysia Department of Safety and Health [13–17]. Within the period of 2007 and 2015, the highest number of fatalities recorded in construction industry were 95 (2007) and 88 (2015). In this period, percentages of fatalities in construction industries are within 28.98% and 43.38%. This scenario can best be described as critical and need to be managed immediately. This data is also may not be entirely through considering that there could be an element of occupational accidents underreporting in Malaysian construction industry. Factual statistical data retrieved from the DOSH cannot indicate the actual and absolute construction safety and health scenario in Malaysia [18]. Mechanism in solving this issue is being studied by respectable Malaysian government agencies and researchers.

Table 1. Fatalities in Malaysian construction industry

Year	Total of fatalities	Total of fatalities in construction industry	Percentages of fatalities in construction industry (%)
2007	219	95	43.38
2008	239	73	30.54
2009	224	71	31.70
2010	185	66	35.68
2011	176	51	28.98
2012	191	67	35.08
2013	185	69	37.30
2014	204	72	35.29
2015	214	88	41.12

3 Human Element as the Contributing Factor Towards Construction Accidents

A framework representing causes of occupational accidents and illnesses was constructed through work previously done by others in the field of occupational safety and health in construction industry (Fig. 1). This framework was used to study management of occupational safety and health in Malaysian residential construction industry in Pulau Pinang [19]. This framework focuses on both the immediate and underlying causes of occupational accidents and illnesses in the construction industry. The framework comprises of immediate causes (human and worksite elements) and underlying causes (management and external elements).

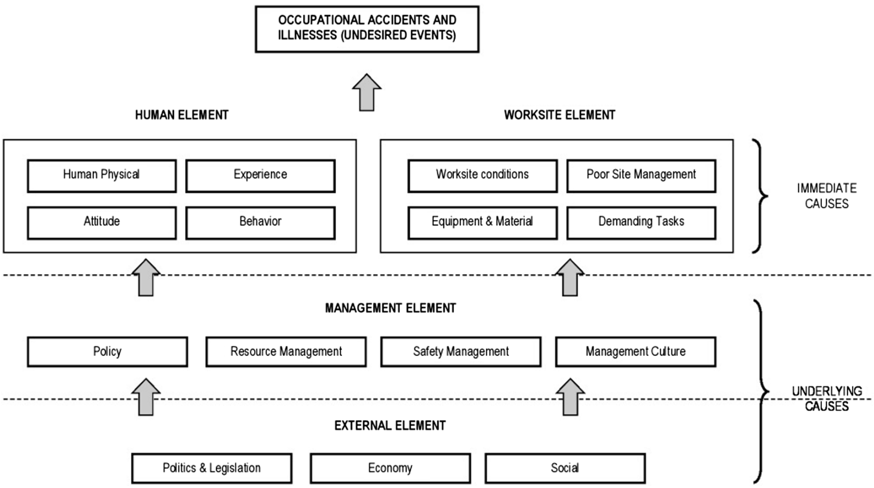

Fig. 1. Causes of occupational accidents and illnesses in construction industry

Human and worksite elements are considered the closest contributing factors towards occupational accidents. Therefore, all the items that were included in these elements are under the consideration that they are causes that are easy to be identified during investigation compare to the underlying causes that require comprehensive investigation approach. External element can be considered the most distant of causes followed by the management element. Management element deserved to be mentioned specifically as one of the underlying factors as it brings another dimension of causes compare to the external element that is wider in scope. In this paper, focus will particularly be given to human element consisting of human physical, experience, attitude and behavior factors.

Human physical is being defined as aspects that involving issues related to human body in terms of physical and physiology. Items that have been taken into account are size, strength, and stamina [20]; body capabilities - tiredness, pain, drug addiction and alcohol intake [21]; health condition and stress [22].

The second factor in the human element is experience that comprises of working experience, knowledge and skill [20]. Safety knowledge has a major influence positively on safety participation [23]. This factor is being defined by including items such as competence, reaction times, information overload, inadequate experience, aptitude for task and literacy/numeracy [22]. Experienced workers tend to adhere to procedures and willing to report small-scale accidents [24].

The third factor that contributed to the human element is attitude. Human attitude is among the main contributors to accidents in construction industry [25]. Hale et al. [22] stated that issues that could be associated are motivation/morale, compliance, complacency, overconfidence, risk perception and 'ownership' of safety issues. Management and workers attitude towards safety have a significant impact on safety performance and awareness [3].

Another important aspect of human element is the behavior that closely related to unsafe act. Holt [26] has distinguished unsafe act as lapses, mistakes, routine violations, situational violations and exceptional violations. Unsafe act is an immediate cause of accidents but it is not the basic or fundamental problems [27]. Lack of skill was the main cause of unsafe behaviors at the construction sites [28]. Behavioral characteristics of workers such as reluctance and complacency towards safety matters can be related with ignorance [29].

4 Method

A total of 13 housing construction projects in Pulau Pinang, Malaysia were chosen. There are seven high-rise and six low-rise housing projects that were selected according to these conditions: i. all the projects were listed with Ministry of Urban Wellbeing, Housing and Local Government of Malaysia and fulfill the definition of housing development according to Housing Development (Control and Licensing) Act 1966 - Act 118 [30]; ii. these projects are not mixed in nature and; iii. construction commenced before December 2013.

Pulau Pinang is separated into two parts comprising of the island and the mainland. There are five districts (Southwest, Northeast, North Seberang Perai, Central Seberang

Perai and South Seberang Perai) that make up the state of Pulau Pinang. This research focused only on Pulau Pinang island covering Southwest and Northeast districts. This study also considered the costs of the projects because Occupational Safety and Health Act 1994 - Act 514 [31] stated that "The employer of the following class or description of industries shall employ a safety and health officer: (b) any work of engineering construction where the total contract price of the project exceeds twenty million ringgit" (approximately 4.84M USD). A quantitative method using questionnaire with the support of qualitative approach of in-depth interview was employed.

4.1 Questionnaire

Application of questionnaire is to obtain data related to attitude, perception, believes and choices rather than facts [32]. 52 respondents from low-rise housing construction projects and 83 respondents from high-rise housing construction projects were involved in this study. 50% of respondents were selected for every project. All the respondents chosen are Malaysian citizen. The respondents consist of labor workers, semi-skilled workers, skilled workers, supervisors, engineers, contractors and occupational safety and health officer (SHO).

One set of questionnaire was prepared consisting three main aspects. These aspects are Section A (respondents demographic), Section B (contributing factors of occupational accidents and illnesses in construction industry) and Section C (the risks of occupational accidents and illnesses in construction industry). Almost all the questions were designed as close-ended. The questionnaire is rated using Likert scale of 1 (strongly disagree) to 5 (strongly agree) and Likert scale of 1 (very low) to 5 (very high) for Section B and Section C respectively. However, only results associated with Section B with the focus on the human element will be discussed in this paper.

Overall there are 45 questions for human element, 30 questions for worksite element, 40 questions for management element and 12 questions for external element. The distribution of questions for the sub-elements in Section B of the questionnaire is presented in Table 2. Besides that, a scoring system was developed to help with the classification of the results obtained throughout the study [19]. The scoring system is shown in Table 3.

Table 2. Overall suitability scale

Mean interval scale	Mean value scale
1.00–1.80	Strongly disagree
1.81–2.60	Disagree
2.61–3.40	Slightly agree
3.41–4.20	Agree
4.20–5.00	Strongly agree

Table 3. Scoring system for contributing factor towards construction accidents

Grade	Measurement scale	Description	Proposed action
1	85–100	Very strong influence	Detailed analysis with immediate action
2	70–84	Strong influence	
3	55–69	Slightly strong influence	Improve existing management system
4	40–54	Moderate influence	
5	25–39	Weak influence	Continuous monitoring
6	10–24	Very weak influence	
7	0–9	No or minimal influence	

For the quantitative study, descriptive and inferential analyses were utilized in analyzing the results that were obtained. Firstly, for the descriptive analysis, results were discussed in terms of frequency, percentage, mean value and standard deviation. Table 4 shows the overall suitability scale that was applied for the Likert scale in this study to define the mean value results obtained. The reliability of the questionnaire was tested using Cronbach's alpha analysis. Results of the reliability test are being presented in Table 3. In terms of inferential analysis, Spearman's rank correlation was applied to understand the relationship of the elements that were tested. In order to compare the perceptions between the high-rise and low-rise projects personnel, Mann-Whitney U was utilized. The hypotheses set for this analysis are as presented below:

H_O: the mean ranks of the two groups are equal.
H_A: the mean ranks of the two groups are not equal.

Table 4. Cronbach's alpha reliability test

Element	Sub-element	Number of items	Cronbach's alpha coefficient
Human	Human physical	9	0.854
	Experience	11	0.840
	Attitude	12	0.871
	Behavior	9	0.933
Worksite	Worksite condition	8	0.907
	Poor site management	8	0.949
	Equipment and material	6	0.927
	Demanding tasks	4	0.846
Management	Resource management	7	0.945
	OSH policy	4	0.925
	Safety management	18	0.964
	Management culture	7	0.919
External	Politics and legislation	5	0.931
	Economy	3	0.888
	Social	3	0.881

4.2 In-Depth Interview

13 respondents were selected for the interview. One respondent was chosen from each housing construction projects. These respondents can be classified as personnel at management level that responsible in making decisions regarding the aspect of OSH at the construction sites. In Malaysia, it is optional to hire an SHO for construction project lower than RM 20M (4.84M USD). Therefore, for project without SHO, project managers were interviewed. Eight of the respondents were SHO and the other five respondents were project manager. Theory thematic analysis was utilized in analyzing the results of the interview.

5 Results and Discussion

135 respondents were chosen for the questionnaire and 13 respondents from 13 housing construction projects were interviewed. In this section, results of human element (human physical; experience; attitude; and behavior) are presented and discussed.

The first factor in the human element is the human physical. In this factor (Table 5), four items registered the mean value scale of "Agree", four items as "Slightly Agree" and one item as "Disagree". The most significant items are "workers are intoxicated or under drug effects", "poor health condition", "workers are under stress or tension" and "suffering from extreme fatigue". The conclusion is that the respondents perceived that items related to physiological aspect are more critical. On the other hand, items related directly to the aspect of human physical ("unsuitable height" and "unsuitable body size" are deemed less significance.

Table 5. Factor of human physical as causes of occupational accidents

Item	Mean value	Mean value scale	Measurement scale (%)
Unsuitable height	2.58	Disagree	40
Unsuitable body size	2.76	Slightly Agree	44
Lack of strength	3.19	Slightly Agree	55
Lack of stamina	3.25	Slightly Agree	56
Suffering from extreme fatigue	3.64	Agree	66
Poor health condition	3.66	Agree	67
Workers are physically disabled	3.29	Slightly Agree	57
Workers are intoxicated or under drug effects	3.70	Agree	68
Workers are under stress or tension	3.65	Agree	66

From the interview regarding this factor, health issues are things that need to be given attention as it can contribute towards occupational accidents at construction sites. It was also concluded that human physical does play some role in contributing towards

Table 6. Factor of experience as causes of occupational accidents

Item	Mean value	Mean value scale	Measurement scale (%)
Lack of knowledge and information	3.73	Agree	68
Too much knowledge and information (leading towards confusion)	3.00	Slightly Agree	50
Lack of skills in conducting tasks	3.46	Agree	62
Lack of experience and training in conducting tasks	3.61	Agree	65
Unqualified to do tasks	3.65	Agree	66
Workers experienced occupational accidents and illnesses	3.25	Slightly Agree	56
Workers experienced near-miss	3.25	Slightly Agree	56
Workers never experienced occupational accidents and illnesses	3.12	Slightly Agree	53
Highly experienced workers causing neglecting of OSH aspect	3.34	Slightly Agree	59
Difficulties in language and communication	3.67	Agree	67
Problems with reading and counting	3.30	Slightly Agree	58

occupational accidents and illnesses in the industry. However, a few respondents perceived this factor as less dominant.

The second factor is experience and the results are presented in Table 6. Five items are classified as "Agree" and the other items as "Slightly Agree". The most significant causes in this sub-element is "lack of knowledge and information". Risks of occupational accidents and illnesses increase if workers have inadequate information and knowledge [28]. Other items that are being perceived as significant are "difficulties in language and communication", "unqualified to do tasks", and "lack of experience and training in conducting tasks". Insufficient training may lead to occupational accidents in the construction industry due to lack knowledge, education and skills in identification of the accidents risks [25].

From the interviews that were conducted, most of the respondents stated that insufficient knowledge and information regarding tasks being assigned and safety aspect contribute towards accidents and illnesses in the construction industry. Due to the insufficient knowledge and information, workers might have less awareness in terms of OSH and lack of ability to evaluate OSH risks. It is important for workers to be well-versed in OSH related to process, accidents risks, and prevention steps [29].

Table 7 shows the results obtained for the third factor. The respondents classify seven out of twelve items being tested in the attitude factor as "Agree". The other five items are classified as "Slightly Agree". Three of the most significant items are "workers do not prioritized safe working procedures", "workers underestimate occupational accidents and illnesses risks", "workers are stubborn, arrogant, selfish or

Table 7. Factor of attitude as causes of occupational accidents

Item	Mean value	Mean value scale	Measurement scale (%)
Workers do not prioritized company performance and reputation	3.33	Slightly Agree	58
Workers do not prioritized OSH policy	3.71	Agree	68
Workers do not prioritized safe working procedures	3.79	Agree	70
Workers satisfy with their individual performance	3.44	Agree	61
Workers are highly overconfident	3.61	Agree	65
Workers underestimate occupational accidents and illnesses risks	3.79	Agree	70
Workers are stubborn, arrogant, selfish or showing off	3.78	Agree	70
Workers with defeatist attitude	3.19	Slightly Agree	55
Workers are hesitant or having difficulty in making decisions	3.27	Slightly Agree	57
Workers prioritizing in fulfilling basic needs	3.29	Slightly Agree	57
Workers prioritizing in fulfilling psychological needs	3.27	Slightly Agree	57
Workers prioritizing in fulfilling self needs	3.41	Agree	60

showing off" and "Workers do not prioritized OSH policy". The results demonstrate that workers attitude and proper implementation of OSH management program are required concurrently. Workers attitude impact OSH performance in construction industry significantly [25]. Attitude was identified as the main cause of occupational accidents and illnesses in the interviews. Workers neglecting OSH risks was highly mentioned by the respondents.

Table 8 shows 11 items that were tested under the behavioral factor. All the items produce mean value scale of "Agree". The most significant items perceived from the respondents are "workers following wrong procedures", "error due to lack of focus/distracted", "unsafe working practices pursuant to the routine of a group/organization", and "workers violate the rules due to limited time". It can be seen that most of the significant items mentioned can be characterized as unintentional error.

Through the interviews that were conducted, behavior is the most significant in influencing OSH level in the construction industry. There are mix responses in emphasizing the significance of unintentional error and intentional violation by the workers in contributing to construction accidents.

Comparison of perception between high-rise and low-rise residential construction respondents towards human element is presented in Table 9. The mean values achieved for both group of respondents are very close and most of the results fall in the same categories of mean value scale.

Table 8. Factor of behavior as causes of occupational accidents

Item	Mean value	Mean value scale	Measurement scale (%)
Error due to lack of focus/distracted	3.70	Agree	68
Error due to complicated procedures	3.58	Agree	65
Lengthy period for the tasks	3.57	Agree	64
Error due to wrong reasons/objectives	3.46	Agree	62
Workers following wrong procedures	3.73	Agree	68
Unsafe working practices pursuant to the routine of a group/organization	3.64	Agree	66
Workers violate the rules due to limited time	3.64	Agree	66
Workers violate the rules due to pressure.	3.59	Agree	65
Workers violate the rules due to unexpected problems	3.61	Agree	65

Table 9. Comparison of perception between high-rise and low-rise residential construction respondents

Sub-element	Mean value		Asymp. Sig. (2-tailed)
	High-rise	Low-rise	
Human physical	3.38	3.18	0.146
Experience	3.39	3.41	0.872
Attitude	3.51	3.46	0.358
Behavior	3.60	3.63	0.701

Through Mann-Whitney U analysis that was conducted, all Asymp. Sig. (2-tailed) values obtained are higher than 0.05. Therefore, the null hypothesis cannot be rejected. It shows that there is no significant difference in perception between both groups of respondents.

Spearman's rank correlation test was utilized to understand the relationship of the human element towards construction main occupational accidents. The relationships between falling from elevation and human physical (0.417), as well as experience (0.407) are the most significant. Meanwhile a relationship between caught and trapped in between or inside objects, machineries, or structures and experience (0.217) is the least significant in human element.

Human physical registered highest correlations towards falling from elevation and falling at a same level. In terms of experience, the most critical correlation can be seen towards falling from elevation, and hit by vehicles. Relationships between attitude and falling from elevation, as well as hit by falling objects or structures are the most significant in this factor. Finally, behavior is the least significant factor, registering lowest correlation for five of the seven occupational accidents being tested. Full result of the analysis is presented in Table 10.

Table 10. Comparison of perception between high-rise and low-rise residential construction respondents

Type of accidents	Spearman's rank correlation			
	Human physical	Experience	Attitude	Behavior
Falling from elevation	0.417**	0.407**	0.385**	0.310**
Falling at a same level	0.392**	0.374**	0.319**	0.262**
Electrocution	0.294**	0.332**	0.336**	0.219*
Hit by falling objects or structures	0.356**	0.371**	0.370**	0.308**
Hit by moving and non-moving objects or structures	0.387**	0.373**	0.338**	0.301**
Hit by vehicles	0.323**	0.388**	0.348**	0.328**
Caught and trapped in between or inside objects, machineries or structures	0.248**	0.217*	0.238**	0.260**

** Correlation is significant at 0.01 level (2-tailed)
* Correlation is significant at 0.05 level (2-tailed)

6 Conclusion

Construction industry is an important sector enhancing the Malaysian economic towards developed country status. The fatalities rate for construction industry in Malaysia is very high. It covers approximately around 28.98% and 43.38% of total occupational fatalities within the period of 2007 to 2015. The numbers certainly proved to be a calling for all responsible parties in Malaysian construction industry to give special attention to OSH in the industry.

In this study, four sub-elements were tested for human element as contributing factor towards occupational accidents in Malaysian construction industry. The highest mean values were obtained for behavior (3.61) and attitude (3.49). Behavior and attitude are much related. These sub-elements are significant components leading to unsafe act by the workers. All of the sub-elements were categorized as "Agree" except for human physical.

There is no significant difference between the perception of the group of respondents from the high-rise and low-rise residential construction industry. Although, the risk of occupational accidents exposed in the high-rise residential construction is potentially higher due to its nature and size of projects, both groups tend to have similar perception towards human element as causes of occupational accidents.

In terms of correlation between human element and main occupational accidents in construction industry, significant relationships were established. This is aligned in references to the major influences of human factor in causes of occupational accidents. It is important to understand the components of the human element, in order to manage it. Throughout this study, it can be concluded that attitude and behavior are the most significant sub-elements that require great attention while human physical is the least significant.

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Lessons Learned from Analysis of Los Frailes Tailing Dam Failure

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Abstract. Tailing dams are used to store mining tailings as uneconomic fraction of an ore after separating the valuable fraction. Tailing dams are mostly hazardous. Therefore, release of a large amount of tailings could lead to serious and long term ecological effects with very high cleanup costs. A literature survey shows that the main causes of tailing dam failure are poor design, improper site, irresponsibility and lack of control. To avoid of tailing dam failure awareness about the root causes and the severity of impacts on environment and human health is very important. This study is focused on a case to identify the causes as a base for proposing some important safety factors to prevent failure of tailing dams. The past experiences show that efforts should be put on prevention rather than reacting after the event.

Keywords: Mine tailing dam failure · Dam failure environmental impacts · Tailing dam design

1 Introduction

A tailings dam is typically an earth-fill embankment dam which is used to store mining tailings as uneconomic fraction of an ore after separating the valuable fraction [1]. Tailings could be solid, liquid, or slurry of fine particles. Solid wastes are often used as part of the tailing dam structure itself. Tailings of many mines such as lead and zinc, copper, gold and uranium, contain toxic substances, which pose big challenges for the long term containment.

Tailings dams rank among the largest engineered structures on earth. Among them The Syncrude Mildred Lake Tailings Dyke in Alberta, Canada, is the largest tailing dam structure on earth by volume with about 18 km long and from 40 to 88 m high [1].

It should be noted that tailing dams are designed for permanent containment. Therefore, design, and control during the construction and operation are very important tasks to avoid structural failure.

Tailing dams are often built with steep slopes using the solid fraction of the mining wastes/tailings thereby saving on cost [2]. In fact, preventing structural failure of tailing dams is an important task in mine waste management. Generally these tailing dams are vulnerable to failure due to poor design, constructing dyke by solid waste materials from the mining operation, lack of standards and regulations on design, specially in developing countries and high maintenance cost after mine closure [3].

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The world tailing dam failure rate over the last century is estimated as 1.2% for 18401 mine sites. This rate is much higher than the failure rate of the conventional water dam, which is reported to be as 0.01% [4].

In recent decades mining industry has experienced several tailing dams failure in association with very costly outcomes. Some of them are shown in Table 1.

Table 1. Some historical tailing dam failure [5]

Date	Location	Company	Mine type	Amount of release	Impacts
25 Apr. 1998	Los Frailes (Spain)	Boliden Ltd.	zinc, lead, copper, silver	4–5 million m^3 of toxic water and slurry	Thousands of hectares of farmland covered with toxic slurry
30 Jan. 2000	Baia Mare, Romania	Aurul S.A., Australia (50%), Remin S.A. (44.8%)	gold recovery from old tailings	100,000 m^3 of cyanide-contaminated liquid	Contamination of the Somes/ Szamos stream, tributary of the Tisza River, killing tonnes of fish and poisoning the drinking water of more than 2 million people in Hungary
4 Oct. 2010	Kolontár, Hungary	MAL Magyar Aluminium	Bauxite	700,000 m^3 of caustic red mud	Several towns flooded, 10 people killed, approx. 120 people injured, 8 km^2 flooded
4 Nov. 2012	Sotkamo, Kainuu province, Finland	Talvivaara Mining Company	nickel, (uranium by-product planned)	Hundreds of thousands of m^3 of contaminated waste water	Nickel and zinc concentrations in nearby Snow River exceeded the values that are harmful to organisms tenfold or even a hundredfold, uranium concentrations more than tenfold
7 Aug. 2014	Buenavista del Cobre mine, Cananea, Sonora, Mexico	Southern Copper Corp.	Copper	40,000 m^3 of copper sulphate	Flow into the 420 km-long Bacanuchi river, 800,000 people were directly affected

Shahid Azam and Qiren Li [2], have carried out a world wide analysis regarding tailing dam failure. Analysis has been done on 18401 mining sites over a time period covering last century called as pre-2000 (1910–1999) and post-2000 (2000–2009) events. They could identify 198 pre-2000 failure events and 20 post-2000 failure events. Number of tailing dam failures in the period of 1910–2009 are shown in Fig. 1.

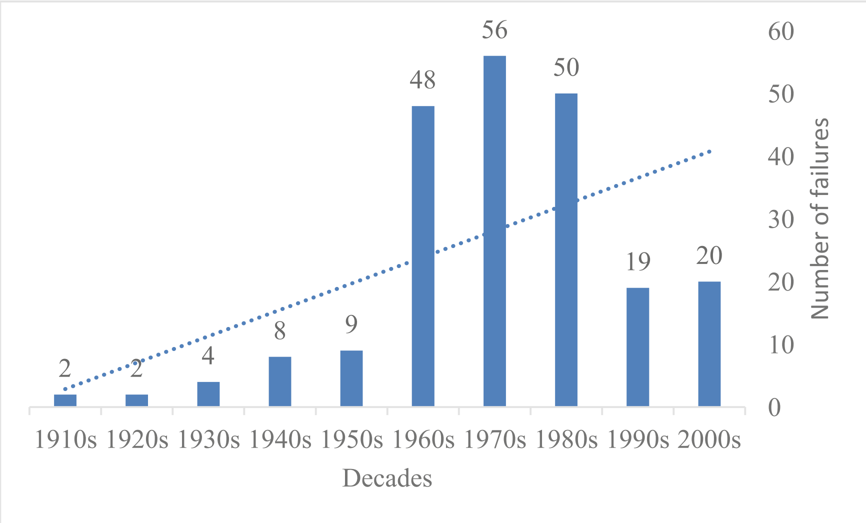

Fig. 1. Tailing dam failure over the time. Adapted from [2]

As far as the regional failures are concerned, of 198 pre-2000 cases most of the accidents have been occurred in North America (36%), Europe (26%) and South America (19%) respectively. Looking at the 20 post-2000 cases of the sites under the study, Europe and Asia are blamed for 60% of the failure events in this period. Table 2 shows regional failure case distribution in the of the study carried out by Azam and Li [2].

Table 2. Regional tailing dam failure (1910–2009). Adapted from [2].

Regions	North America	South America	Europe	Asia	Africa	Australia
Number of studied mine sites	8652	1825	1168	1584	1624	3548
Failure cases (pre-2000)	72	38	52	17	12	7
Failure cases (post 2000)	5	2	6	6	1	0

As it is shown in Table 2, failure cases have increased in Europe and Asia during post-2000.

According to the literature, the main causes of tailing dam failure could be overtopping, weather (climate changes), poor management, and poor design and construction [2].

The main impacts of tailing dam failure are environmental damage, health problem, human losses and capital losses such as infrastructure, agriculture farms and dam itself.

Tailing dam events which have been associated with significant impacts on environment, human health and life and capital in some parts of the world could be considered as a warning for improving safety criteria in tailing dam design and operation. It should be noted that a large number of tailing dam incidents remain unreported specially in developing countries. This could be a serious hinder for development of safety standards and regulations in this field.

This study is focused on failure cause analysis through applying Swiss Cheese Model which has been developed by Reason [6]. The Model will be applied to identify the root causes of failure of Los Fraile tailing dam, which occurred in Spain 1998. The goal of the study is to find the basic criteria, which are needed to design a safer tailing dam.

2 Case Description

On April 25, 1998, the Los Frailes lead-zinc mine experienced a foundation failure due to sliding surfaces in the ground, leading to the dam breaking and releasing between 4 and 5 million cubic meters of mine tailings. The mine tailing, being acidic and containing several heavy metals, poured into the nearby river Rio Agrio. The river rose 3 m, flooding thousands of hectares of farmland. This has later been called the Doñana incident. Rio Agrio is a tributary to Rio Guadimar, which flows through Doñana National Park. The water eventually finds its way into the Mediterranean. It was therefore crucial to gather and handle the waste as soon as possible. However, the cleanup operation took a total of three years and had an estimated cost of €240 million [7].

The Los Frailes mine is owned by a Spanish subsidiary of the Swedish/Canadian company Boliden. Boliden has, though not presenting a report of their own, stated that the accident was caused by force majeure, and could therefore not be predicted and Boliden could not be blamed. However, this statement has been criticized. In fact, the problem with sliding surfaces in the ground was identified two years earlier [7] (See Fig. 2).

The bottom of the dam consisted of marl. The chemicals contained in the dam reacted with the calcium carbonate in the marl, causing it to decompose. Thus, the mechanical stability of the soil was deteriorating. Boliden had recently been applying for a licence for doubling the dam's capacity. Therefore, one can raise hypotheses that the dam was deliberately overloaded. Boliden has refused to pay any compensation for damages, still referring to the accident as a result of force majeure.

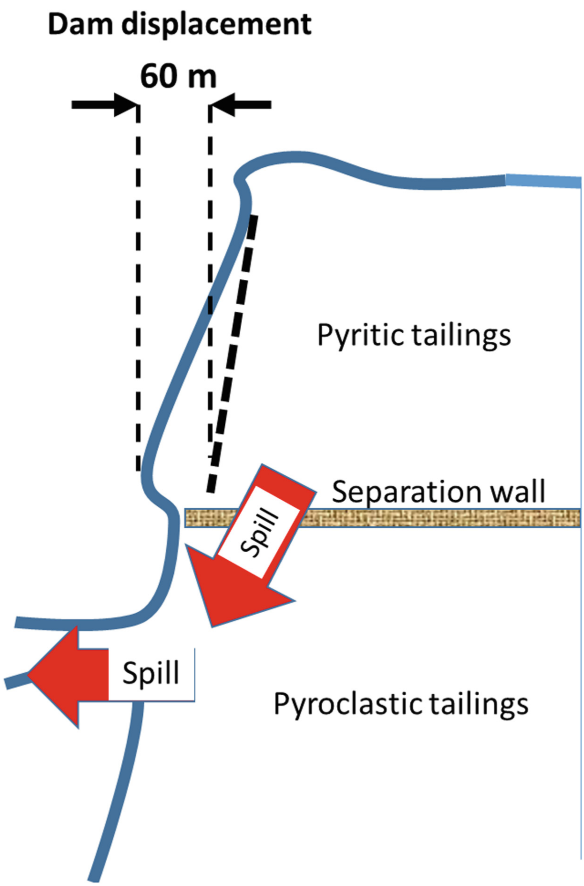

Fig. 2. Spill due to sliding surfaces in the ground

3 Swiss Cheese Model Description

The Swiss Cheese Model as shown in Fig. 3, is developed by James Reason to analyze causes that lead to an accident. According to Reason, each slice of cheese represents a barrier or defense layer that prevent the hazard from passing through, leading to an accident subsequently [8]. Example of barriers includes adopting a properly designed safety system, proper procedures of maintenance and provides adequate training to the workers. However, these barriers might not be functioning perfectly. There might be weaknesses present in these defense layers and each of the weaknesses represents a hole on the slice of cheese [9]. The weaknesses of the defense layer might be arisen from latent condition or active failure [6]. Both failures have the potential to trigger an accident. Latent failure is inevitable within the system and it normally exists due to the decisions made by the top management who sets the goal [9]. There are two major effects of the presence of latent failure in the system. It either creates a working environment which is prone to error-making condition or a permanent hole on the defense layer that weaken the whole system [6]. Latent failures remain dormant in the system for a long period of time before they combined with active failure to trigger an accident [6]. This may be introduced at the time a tailing dam was designed or may be associated with management decisions and policies. Active failure is due to the unsafe act committed by people who are working on the decision or those who are working in front of the system [6]. The unsafe act can be further classified as intended or unintended actions. Intended actions can be categorized as mistake or violation whereas unintended action includes slip and lapse [6]. The position of the holes on the defense layers is continuously changing [6, 8]. These holes are located at different positions on each defense layers. Hence, even if there are holes on the defense layer, accident might not occur because hazards might not be able to penetrate the subsequent defense layer due to different positions of the holes (see Fig. 3). Conversely, when the holes on all the defense layers are aligned into a straight line, there is a potential that hazards could penetrate through the layers and trigger an accident (see Fig. 3).

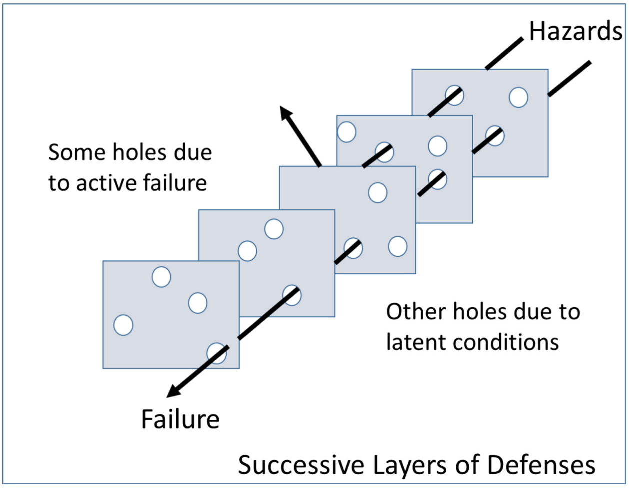

Fig. 3. Swiss Cheese Model with either non-aligned holes on the defense layers or aligned holes on the defense layers (Adapted from [10])

It should be noted that most accidents (or system failure) can be linked to one or more of five levels of failures: organizational influences, unsafe supervision, preconditions for unsafe acts, the unsafe acts themselves and in adequate defenses.

4 Analysis of the Accident

The failure of Los Frailes tailing dam has been analyzed using the Swiss cheese model (see Fig. 4). For the analysis of the case, 5 safety barriers were recognized as shown in Fig. 4.

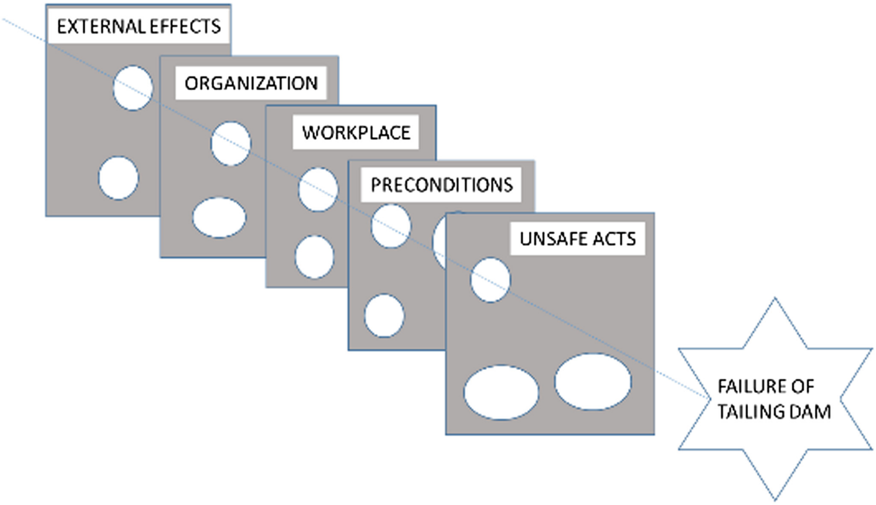

Fig. 4. Safety barriers recognized in Los Frailes Tailing Dam

The analysis of the case is summarized in Table 3.

Table 3. Results of the analysis of the case under the study

Category	Description
External effects	● No serious enforcement/didn't follow the directives ● Poor control
Organization	● Poor design ● Improper site selection ● No care about the reports of two consultancy firms like Geocisa and Golder Associates AB, which found the weak points two years before the failure ● No coordination between two projects for building the tailings dam ● No safety culture ● Neglecting the regulations
Workplace	● No management change policy ● No monitoring and control: Lack of instruments for working correctly due to absence of working inclinometers ● Neglecting the regulations ● No risk assessment and emergency planning and responses ● Poor maintenance and no reporting system
Preconditions	● Type of material in the soil (marl) ● Dam built at the top of expansive clays ● Water presence where dry conditions were expected ● High pressure of water in the clayey foundation ● No communication ● Lack of knowledge ● Vibration due to the blasting at the nearby mine
Unsafe acts	● Overloading the dam ● Lack of foresight ● Late reaction after awaking of water presence where dry beaches should be expected and even when they found failure with electric cable due dam structure movement ● Problems of the deformations not accounted at all ● No care about not working instruments

5 Results and Conclusion

Analysis of the case under the study shows that lack of safety culture, poor design in terms of ignorance of interfere of soil and tailing material, improper site, irresponsibility, lack of control, no monitoring and reporting have been the main causes for the failure. These problems are mostly due to weaknesses in the protection layers of organization and management. In other word Boliden company has failed to create a security base to prevent the dam failure. On the other hand, the company has worldwide mining activities experiences. Therefore, it was expected to manage the crisis. This accident and the similar event, which occurs about one per year [4], could cause very harmful environmental crises. Therefore, more attention should be payed, in design, site selection, monitoring, control, and finally effective crises management to minimize the serious impacts on the environment. The results from the Los Frailes tailing dam failure were used to give general recommendations for integration of safety into the life cycle of tailing dams. These includes:

- *Design and Site Selection:*
  - site assessment (geology, seismicity, climate, upstream catchment area,…) and selection
  - hazard scenarios identification considering heavy rain, flood, blasting, earthquake etc.
  - analysis of anticipated dam failure impact (travelling path of slurries, downstream land use and water use,…)
  - selection of embankment type
  - assessing interferes of soil and the tailing material
- *Construction:*
  - Using right technology and materials
- *Observation and control:*
  - regular monitoring of dam movements,…
- ***Improve stability of existing tailings impoundments*** by for instance construction of diversion dams to prevent flood inflow, smoothing of slopes, etc.
- ***Considering long-term safety and failure modes other than complete embankment failure*** (such as seepage, dust, long-term erosion, bio-intrusion, etc.)

While embankment breaks are the most spectacular failure mode for tailings dams, the long-term hazards should not be neglected either. This requires efficient measures to contain these hazards in the long term.

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Blame Culture in Workplace Accidents Investigation: Current Model Discussion and Shift Requirements for a Collaborative Model

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Abstract. The objective of this study is to discuss the Brazilian industrial accident evaluation model in chemical and petrochemical companies located in the metropolitan region of Salvador and to propose a transition model from guilt culture to an environment where workers have equal conditions before companies and can efficiently collaborate in investigations and implementations of countermeasures thus reducing the occurrence or recurrence of unwanted events, a *just culture* environment.

Keywords: Blame culture · Workplace accident · Just culture · Accident evaluation model

1 Investigation os Accidentes and Blame Culture in Companies

The investigation of workplace accidents in Brazil is obligatory and supervised by the Ministry of Labor and Employment through the Regulatory Norms (NR's). NR-4 and NR-5 regulate issues related to the investigation of occupational accidents.

NR-4 establishes the obligation to maintain, for some companies, the Specialized Services in Safety Engineering and Occupational Medicine (SESMT), [1]. NR-5, disciplines the creation of the Internal Commission for the Prevention of Accidents - CIPA in companies, with the objective of preventing accidents and diseases arising from workplace [2]. The CIPA was created in 1944, one of its functions is to participate in the analysis of the causes of diseases and accidents at work and propose measures to solve the problems identified. In addition to the Norms of the Ministry of Labor and Employment, the legislation also provides that any workplace accident or occupational disease must be reported by the company to the National Social Security Institute (INSS), under penalty of fine in case of omission. The instrument of communication to the INSS is the Communication of Accident of Work – CAT.

In Brazil, in addition to the Federal Constitution, the amount of laws that protect the worker is extensive. The effectiveness of this legal protection is hampered by precarious

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supervision, as well as by the lack of adaptation to the reality of the dynamics of labor relationships. The importance of accident prevention and investigation may seem obvious, but in practice failures as inadequate methods of analysis and prevention, compromise the representativeness of results [3].

In the investigations carried out by Brazilian companies, the understanding of the accident predominates as a simple event, originated from the contribution of a few causes, chained in a linear and deterministic manner, favoring individual behavior and violation of safety norms [4].

Criticizing the approach to the cause of accidents, Hollnagel [5] argues that the occurrence of an accident is related to the existence of a number of coincident factors, at a given moment. The explanation of the accident is constructed through the analysis of the set of factors and their conditions.

It is necessary to take into account the multiplicity of factors involved and the possible relationships between them, seeking to reveal important conditions for preventive actions. The observation of the scenario, the reconstruction of the facts, the analysis and appropriate treatment of the information, are fundamental for the implementation and follow-up of preventive and corrective actions. Such actions are important to strengthen the safety culture and appreciation of the employee. On the other hand, identifying the professional involved in an accident for the purpose of assigning him the fault and responsibility for the damages caused does not contribute to the reduction of accidents.

In assigning responsibility to the employee, the company seeks to restrict the scope of accountability, avoiding its linkage to higher hierarchical levels. This reduces the size weight of the consequences and responsibility of the event for the company. It also reduces demands on future labor lawsuits and avoids damages to the company's image. The worker found guilty is accused of not following security procedures, not devoting himself to training received, been reckless in carrying out the task. The company, on the other hand, considers that it has provided all the means to carry out the work in an absolutely adequate and safe environment and conditions. Regarding the legal aspect of liability for workplace accidents, Brazilian law provides that the employer may be held liable in the civil, criminal, social security and labor courts.

In the civil area there is an obligation of indemnification for moral damages and/or material [6]. The employer, however, may be exempted from the responsibility of compensating the victim, in the event of his/her exclusive fault, as established in Brazilian law and jurisprudence [7]. In the criminal sphere, the employer may suffer penalties such as restriction of rights and deprivation of liberty. The company may be punished through its partners and directors, responsible for management [8].

In the social security area there is an obligation of the employer to contribute, relative to its employees, to the Social Security service [9]. With regards the labor area, the employer is responsible for maintaining the stability of the injured employee for a period of 12 months after the cessation of the accidental sickness aid.

2 Does Human Error Reveal or Hide the True Causes of Accidentes?

Security management, centered on the direct relationship between human error and workplace accidents, despite many criticisms, seems to be sufficiently entrenched, requiring not only discourse, but technical and behavioral changes. With this posture, important aspects of accidents are no longer assessed or evaluated superficially. For example, problems or malfunctions in systems related to the execution of the task, whose design and management, originate in the company itself, can not be properly analyzed and can lead to accidents.

For Reason [10] human error must be understood as a consequence rather than as a cause of accidents. This understanding opens up an opportunity for an extension of the horizon of the accident evaluation, allowing a preventive gain.

Alongside the technical questions regarding production processes and their barriers to prevention and mitigation of failures, people's issues can not be overlooked. For Ávila [11] the industry should expand its analysis of near accidents and accidents, contemplating social and leadership aspects in the process of human error prevention. Develop skills related to work activities, identify and analyze failures under various aspects, including behavioral is important in accident prevention. Llory [12] recognizes the subjective dimension in accidents at both the individual and the organizational level, in the horizontal and hierarchical relationships historically established in the work environment.

Differences in performance in the execution of tasks are situations that generate opportunities for errors, which in turn, may or may not lead to consequences that lead to accidents. An individual who performs a task more than once will not do so in exactly the same way, this variation stems from the individual's interactions with systems and the intrinsic variability of people's behavior. The choice of action or omission behavior based on received information is a cognitive process influenced by factors such as: training, motivation, humor, stress, technical knowledge, among others, of-sending a position of the performer.

The human error happens when the limit of acceptability of the system is exceeded by action or omission in the execution of the task. This condition results in disturbances in the system that have the potential to cause accidents, depending on the specific characteristics of each system such as complexity, process protection barriers, among others. From the point of view of human error, the challenge for companies security management is to minimize its likelihood of occurrence at all levels of consequences, from almost accident to workplace accidents.

If human error is identified in investigations as the main cause of accidents, what are these companies doing to minimize this fact? What are the factors directly associated with human error that contribute to the occurrence of almost accidents, and accidents in these companies?

3 Methodology

The research considered the hypothesis that the blame culture model prevails in the investigation of accidents in the chemical, petrochemical and oil industries located in the metropolitan region of Salvador, northeastern Brazil, and that changes are needed to reduce number of accidents. The investigation followed the steps described in Fig. 1.

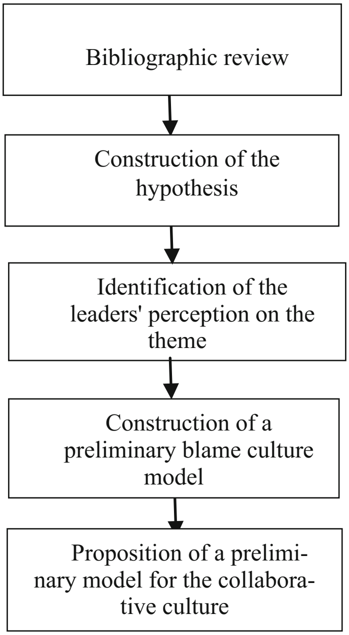

Fig. 1. Steps of the methodology

In order, to collect the survey data, questionnaires were applied and semi-structured interviews were conducted with four professionals working in the areas of safety, occupational health and the environment of medium- and large-sized companies.

Each of these professionals has at least 10 years of experience in their respective areas, in leadership positions and work in companies considered to be high risk. These companies work under severe process conditions such as high pressures, handling and storage of toxic or flammable substances.

The objective was to construct a first perception about guilt in the accident evaluations carried out by the companies surveyed and the elaboration of a preliminary guilt model, based on the results obtained. From the preliminary model of guilt built, the subsequent step was the proposal of a transition model from blame culture to collaborative culture.

The interview and questionnaire elaborated were formatted in blocks of questions with the purpose of evaluating: the existence of a security policy in the company, the commitment of the top management with this policy, the effective investments in security, the accomplishment and adequacy of the training in Safety and its periodic recycling, the existence and adequacy of operational procedures, the systematic investigation of accidents considering technical aspects and human factors, the consequences for the employee involved in an accident at work, the communication of accidents within the company as learning tool.

4 Analysis and Discussion

The interviewees were referred to as: interviewee 1, has 20 years of experience in the area of security, acts as coordinator of safety, health and environment, in chemical company; The interviewee 2 has 10 years of experience in the area of security, acts as production coordinator, in a chemical handling and storage company; The interviewee 3 has 20 years of experience in the security area, acts as security coordinator, in a chemical company producing pigments for paints; The interviewee 4 has 22 years of experience in the area of security, acts as a security engineer and environment in oil company.

All companies have a health, safety and environmental policy. For all those interviewed, job security is a priority in the goals, investments and execution of tasks in the company. The interviewee of the company 1 also informed that this priority is recent in the last 3 years, and due to the change in the control of the company, previously belonging to the financial area, did not prioritize investment in occupational safety.

All companies reported advising the performer of the task, so in doubt as to technical or safety issues, not perform a task and should report the fact to their supervisor. Company 1 interviewee reported that the employee awareness process is slow and difficult since it is a behavior change introduced by the new manager group of the company. All respondents agree that there is an excess of procedures that make it difficult and confusing to perform tasks rather than facilitating their execution.

Regarding training, companies have reported that they seek to first meet the legal requirements and then their internal programs. Some of the internal programs are based on corporate standards, in the cases omitted from the Brazilian legislation or where it is less restrictive. The interviewee 4 reported that his company requires and supervises the contractors regarding the performance of the training. Interviewee 1 reported that he is still adjusting the period of some trainings. It is observed that although all companies train their employees to carry out risky tasks, there is a lack of confidence regarding the adequacy of the training, recycling and updates regarding eventual changes in the process, equipment or other that may impact adversely affect safety.

As for accident investigation, all companies have formal procedures in place. The interviewee 1 attributed the difficulty in the investigation of accidents to the company's fragile safety culture, aimed at punishing guilty parties. Respondent 3 stated that there were no difficulties in the investigation of accidents in his company and credited this fact to his experience and the experience of the investigation team. Interviewee 4 reported difficulties in investigating accidents resulting from excessive bureaucratic demands internal to the company such as the involvement of several hierarchical levels in near accidents, slowing the investigative process. The reports make clear problems that compromise the effectiveness of the investigative process and contribute to the prevalence of culture of guilty. It is observed the direction of the investigation only for the main event, neglecting the set of circumstances and factors related to the accident and its contributions. The bureaucratic hurdles cited by the interviewee 4 not only discourage research but foster the omission of important facts and information. The omission of these facts leads to inertia about situations of near accidents and deviations, hindering the prevention of potential future accidents.

All companies have formal training actions on the factors indicated as the cause of the accidents, but those involved in the accidents are allowed to follow the preventive and corrective actions arising from the investigation. Without an effective incentive policy of the company, this monitoring proves to be unfeasible when returning those involved in the accident to the routine of stressful work.

Three interviewees reported that human factors are considered in the investigation as possible causes of accidents except the interviewee 4 which suggests that investigation should be limited to technical issues. In his opinion, it is up to the medical service of the company to evaluate the physical and psychological conditions of the worker. This positioning suggests a dissociation of the individual's psychic and physical conditions, devaluing stress, fatigue, personal problems and others that directly impact the attention and performance of the task.

The interviewees affirmed the importance of identifying those involved in accidents to reorient them, but they admit to use the accident indicators as a form of evaluation of the employees' performance. Those found guilty of accidents can be punished with warnings and even with dismissal. This approach may result in embarrassment, financial discouragement, and omission of information. This fact creates a non-collaborative environment in the prevention and correction of accidents or near accidents.

Human error was pointed out by all interviewees as the main cause of accidents in companies, followed by lack of training or inadequate training. Considering that all interviewees reported that companies have investments in training, the way of applying these resources needs to be reviewed. The effectiveness of the training is related to a competent instructor, clear language and content relevant to the objective. Also important are the use of learning verification tools and periodic recycling.

The interviewees affirmed the importance of identifying those involved in accidents. Figure 2 represents the relationships between the agents considered as main in the construction of guilt of the victim in workplace accidents, based on the perception acquired with the research carried out.

The main entities involved in the employment relationship are: Company, Worker, State and Society, forming a system of interrelationships. Influencing the interactions between these, external factors such as social aspects, have local or global reflexes, economic aspects can favor certain activities, to the detriment of others. They also exert pressure on the system, the geopolitical aspects of a particular region that provide productive activity and cultural interactions. The emergence of new technologies brings the breakdown of paradigms and causes changes in technique and behavior.

Analyzing the relations between the State and the other entities it is observed that in regard to the company, the society and the worker these relations are imposed by force of law. However, the worker, by legal principle, is considered as the most vulnerable

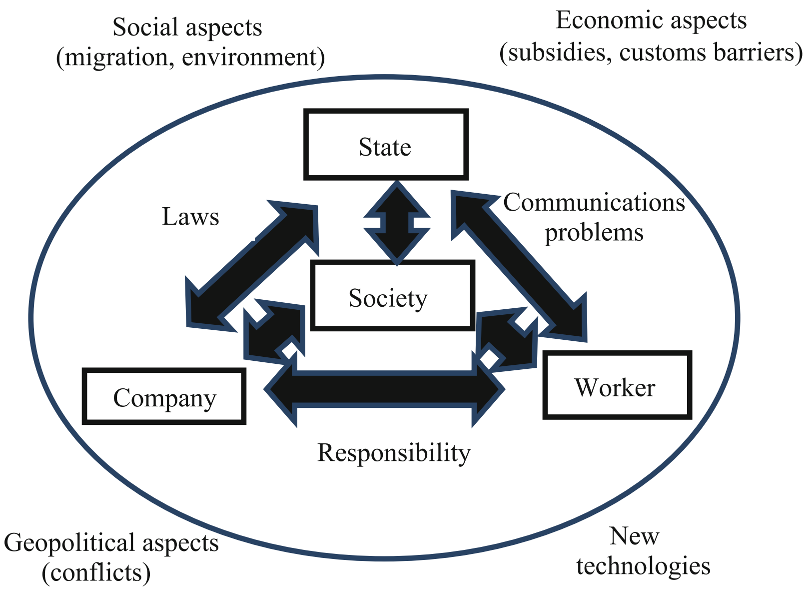

Fig. 2. Blame culture model in workplace accidents based on the research carried out.

side of the labor relationship, and it is up to the State to protect it as a way of guaranteeing balance and justice in the relationship.

The State receives from the company the rendering of accounts of the legal obligations. The latter demands licenses and permissions of operation and modifications in its processes. Society demands the State to fulfill its role of monitoring and fostering social welfare.

In its interactions with the employee, the company establishes requirements for behavior patterns, meeting performance expectations, adopting its safety culture, quantity and quality of results.

The company encourages society to consume goods and services produced by it. Society demands the company to meet its needs, through consumer goods and a responsible attitude on environmental issues.

In relation to the worker, the society demands for a professional and financial rise as well as for the participation in the social initiatives. The employee, in turn, expects the company to recognize by his work and accept as a member from society.

The worker demands the State to see corrected eventual injustices and does it through judicial actions and through the support of the unions. The slowness of the Brazilian justice system and the risk of being dismissed discourages the worker who fails to communicate situations of significant risk.

Figure 3 represents the model of relationships in the process of transition from blame culture to collaborative culture. Relations between the State, Company, Worker and Society are perfected, intensified and new interactions come into existence. In order to simplify the representation of these associations, in Fig. 3, only the new relations are presented, however those present in Fig. 2 remain. The objective is to create a confident environment where those involved can collaborate in minimizing the factors that contribute to the vulnerabilities that result in accidents.

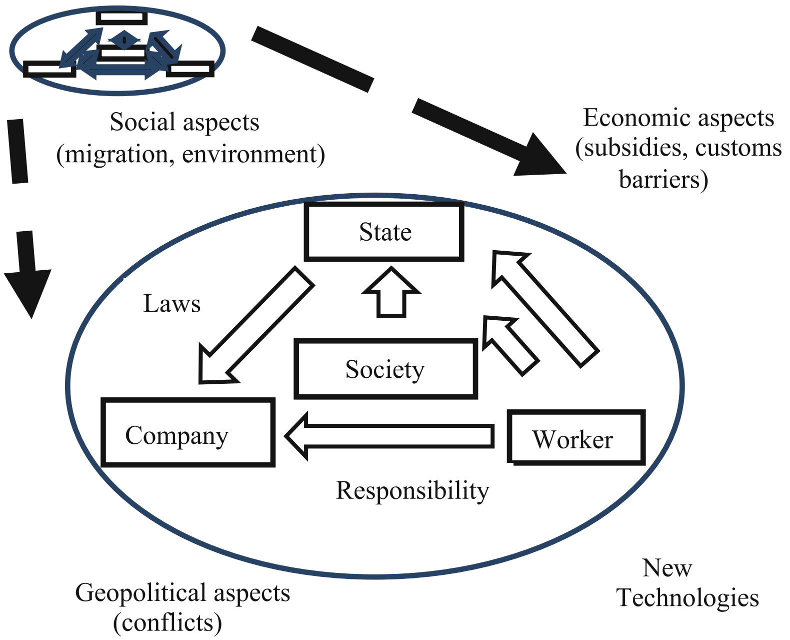

Fig. 3. Proposed model for the transition from blame culture to collaborative culture.

The worker, supported or not by society (class organ), seeks the State's action to implement legal measures with the company, in such a way that it develops a more transparent and integrated relationship with the worker. In this way, enabling the worker to have the confidence and security to participate actively in the investigation processes of accidents. In this environment, it will be possible to widen the scope of the investigation to consider the possible existence of human error as a fact of multiple origin, not as a personified aspect.

5 Conclusion

The presented results allow to conclude that imputation of the guilt to the victim of workplace accident, feeds a process of impunity. In Brazil, this process is favored by the fact that the legal system excludes civil or criminal reparations, when the accidents occur due to "the victim's" exclusive fault.

Even in companies that consider their management systems consolidated and efficient, there is a reactive attitude in the investigation of accidents, blocking communication with the worker, which starts to omit information for fear of being punished. The involvement of top management with the prevention and reduction of accidents must be evident for all workers in order to support the work performed by the other hierarchical levels.

The current model of accident investigation adopted by the companies surveyed is based on guilt and hinders behavior changes and attitudes that produce effective transformations. These transformations are fundamental for a participative security management, which favors the establishment of cooperative relations and solidarity in the work.

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Burning and Electrocution Risk's Evaluation and Prevention Procedures: A Case Study in a Production Work Shop

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Abstract. The aim of the present study is to diagnosis, assess and present prevention procedures of electrocuting and burning risk, taking as a case study electrocuting and burning situations in an Algerian setting "INFRAFER" specialized in the production of railway concrete sleepers, based in Oran. All the workers of the welding and cutting workshop (N = 38) participated in the study. ILO/IEA ergonomic checkpoints were used for the diagnostic of electrocution and burning risks. The Methodology for Analyzing System Failures (MADS) approach was used to assess the risk of electrocuting and burning. The study revealed the following results: (1) a Constant frequency of electrocuting and burning risk facing the workers of the workshop; (2) a strong dose of exposure to risk; (3) a high level of exposure to risk; (4) the risk of electrifying and burning has serious impact but without complications; (5) the level of seriousness calls for rapid intervention. By identifying the priority level, the present study recommended that "collective protection strategy" is the appropriate action to prevent this category of risks.

Keywords: Electrifying and burning hazards · Occupational risks · Assessment procedures

1 Introduction

According to the statistics of International Labor Organization [1], occupational accidents is a universal problem, for it has exceeded 317 million accidents annually, causing more than 2.3 million deaths per year. Occupational risks are multiple in modern society, their causes, types and consequences are multiple too, covering every human activity. One of which is electrical accidents, as electricity is an integral part of modern society, its occupational use is inevitable. But failure to comply with proper rules of use and regulations in dealing with electric installations can be of fatal consequences, beside material losses, injuries, etc., particularly among electric utility personnel. This professional category have additional risk since they work with both high-voltage and high-current equipment, according to Fordyce et al. [2]. Electric accidents are the most fatal of all kind of accidents as it is documented by statistics

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word-wide [2–7]. Electric injuries result from electrical explosions, flashes or direct contact with electrical current [2].

Electric risks in Europe are present in almost every profession according to the European national accident registries [4], in the USA, electrocution is the fifth leading cause of occupational injury death in the United States [5]. Although the data [6] indicate that progress continues to be made in reducing the overall number of electrical injuries, there is more work yet to be done, as has been pointed out by Cawley and Brenner [6]. The highest proportions of fatal occupational electrocutions in the United states have occurred among those employed in the electrical trades and in the construction and manufacturing industries [7].

The situation of occupational safety and health in developing countries is still lagging behind as compared to developed countries. Despite the efforts to limit occupational risks and to promote occupational health and wellbeing in developing countries, the situation of occupational risks is alarming. Although, industrialization has given a significant impact in terms of income distributions and quality of life, but it resulted in increasing number of accidents at workplace [8]. According to Noor et al., the high accident rate in Malaysian manufacturing industries is due to non-compliance with occupational safety and health requirements and lack of safety culture.

Electricity is recognized as a serious workplace hazard, exposing employees to electric shock, electrocution, burns, fires, and explosions. Burning and electrocution hazards are well spread among professions dealing with electricity and electrical equipment [9]. In their study of occupational hazards awareness and utilization of safety measures among welders in Nigeria, Sabitu et al. [10] concluded that the level of awareness of occupational hazards was high among the profession of welders, while their utilization of protective measures against electricity hazards was sub optimal. In a Ghanaian population, Agbenorku et al. [11] noticed an increase in the trend of electrical burns among different demographic and socio professional categories of the population.

According to studies of burning and electrocution risks [9–13], the main causing factors of accidents are the noncompliance with the correct preventive measures, such as: regular inspection of equipment, use of personal protective equipment, lack of necessary competences to handle electric duties, and the non respect of the right procedures and methods during the course of work. These causing factors can be generalized to many occupational safety and health aspects in developing countries, for the work force is generally unskilled or semiskilled, not trained in safe work practices, poorly paid, temporarily employed, exhibit low production rates, besides, the lack of management commitment to safety programs and various safety procedures, as has been pointed out by Koehn et al. [12].

In Algeria, despite the regulations which emphasis the different aspects of risks prevention, studies of occupational accidents [14–16], show that workers in industrial environment are exposed to different occupational risks that can be of fatal consequences. Statistics of the Algerian official bodies are alarming too, the National Institute of Professional Risks Prevention [17], Social Insurances for Salaried Workers [18]. According to the Algerian renewable energy development center (CDER) [19] burning and electrocuting accidents due to the misuse of electrical installations caused 225 accidents with 164 deaths in 2009 (no recent figures are available). But as Allison Haluik [20], points out: “due to its familiarity and everyday use, people are often complacent to electrical hazards and underestimate the risks associated with exposure to electricity". This is a fact, either at home or in work situations.

To tackle the problem of occupational hazards from its roots, and to limit its harmful effects on employees and its negative percussions on production settings and the environment at large, the "priori evaluation of risks" methods seem appropriate. This has become a common practice in many industrial settings in the developed countries. While, in the developing countries the evaluation of occupational risks has not yet reached the "priori evaluation" stage.

The aim of the present study is to determine the priority of action to undertake in order to prevent electrocuting and burning risks facing the workers, through a process of diagnosis, identification and analysis, taking as example electrocuting and burning situations in an Algerian setting "INFRAFER" specialized in the production of railway concrete sleepers, based in Oran, Algeria.

2 Method and Procedures

2.1 Sample

The evaluation process of risks in the railway concrete sleepers production shop floor was carried out by a sample of three (3) production managers, two (2) safety engineers and one (1) electrical engineer (n = 6), called experts in this study, their mean experience in the company was 21.33 (6.25) years.

The evaluation process was carried out on all workers of the shop floor (n = 38), all of them males, with a mean age of 34.45 (8.75) years, and a mean experience in the company of 12.32 (7.55) years. Their distribution among different workstations of the shop floor is seen in Table 1.

Table 1. Shows the distribution of workers according to work stations of the shop floor.

Work stations	Workers (N)
Station (1) welding of metal structure	4
Station (2) Concrete preparation	4
Station (3) Fixation of concrete on metal structure	24
Station (4) Product quality control	6
Total	38

As shown in Table 1, the shop floor of railway concrete sleepers production was divided into four work stations, in which four different tasks were performed by a total number of thirty eight (38) male workers.

2.2 Tools

In order to evaluate the different aspects of burning and electrocuting risks and to propose the adequate preventing actions, that are appropriate to the production of railway concrete sleepers workshop, the following study tools are used:

Ergonomics checkpoints [21]: An ergonomics diagnosis tool elaborated by ILO/IEA in 1996, revised in 2010 was partially used to diagnosis the presence of electrocuting/burning hazards. Eight (8) checkpoints dealing with electrocuting/burning situations in the workplace were used in the present study (see Table 2).

Table 2. Shows the diagnostic results, which confirm the presence of electrocuting/burning hazards in the production shop floor.

Check points no.	Check points items	Propose action
19	Unsafe power tools	Provide protection against power transmission
26	Improper tools insulation	Provide necessary insulation to avoid burns/electric shocks
43	Absence of correct warning signs	Provide correct warning signs and clear instructions
50	Incorrect electric wiring	Train workers to report deficiencies
75	Source of heat not isolate/insulated	Locate machines near the exterior so heat can escape
89	Electric hand-held equipment not well insulated	Arrange regular checking electric devices
90	Unsafe wiring connections	Use appropriate wiring gauges
98	Absence of first aid equipment	Provide easily accessible first aid equipment

Once the presence of electrocuting and burning hazards was confirmed, the present study undertook the evaluation process.

A five steps risks' priori analysis approach "Methodology of Systems Dysfunction Analysis" (MADS) developed by a group of searchers [22, 23], was used to assess the following aspects of electrocuting/electrical burning situations: (1) the occurrence frequency of risk, (2) the dose of exposition to risk, (3) the exposure level, (4) the level of severity, (5) level of risk, (6) and to determine the priority of action to undertake, in order to prevent electrocuting and burning risks facing the workers of work shop floor. To collect data on different aspects of the risks under study, the researchers have used MADS worksheets and observation grid as described in Périlhon [22].

2.3 Procedures

The field study was carried out from January 20th to February 21st, 2016, in the work shop floor of the railway concrete sleepers production company, in Oran Algeria. The range of temperature in Oran during February 2016 was 8°–10° (lowest) and 17°–19° (highest). The rest of physical working conditions inside the workshop were measured by appropriate apparatus, their mean values were: Mean noise level: 79.5 db (11.43), mean light intensity: 473.5 lx. (175.41), mean humidity level: 62.20% (0.89), mean interior air speed: 2.02 m/s. (0.17).

The study was conducted along two stages, namely: the risk's diagnostic stage and the risk's evaluation stage.

2.3.1 Diagnosis Stage

After an initial walk through the work area, and several sessions of consultation with managers, safety officers and workers, eight (8) checkpoints were selected from the ILO/IEA 132 checkpoints, for the diagnostic of electrocution and burning risks. The researchers inspected the indicated checkpoints and the relevant items, reported the proposed action to undertake and the relevant remarks, exactly as indicted in the manual of use the ILO tool [21], results of the diagnosis stage are described in Table 2.

2.3.2 Evaluation Stage

The researchers organized a series of meeting with the six members of the evaluation team (experts), as they are the corner stone in the evaluation process, according to MADS method strategy. The aims of the meetings were to involve the evaluation team members in all the steps and procedures of the evaluation process, and to make them familiar with the present study tools and procedures, as they are going to rate factors, situations and parameters of electrical risk situations.

In order to analyze, evaluate and determine the priority of action to undertake in order to prevent electrocuting and burning risks facing the workers of workshop, the five steps of MADS method were implemented as follows:

Step 1: Estimation of the frequency of exposure to risk, the level of risk detection and the level of severity by the evaluation team, on the relevant worksheet.

Step 2: Estimation of the number of workers exposed to electrical risks, their training level and the risk increasing factors by the evaluation team, on an appropriate worksheet.

Step 3: Collect of observations by the researchers on the time of exposure to the risk spent by the workers, their number and whether they used personal protection equipments (PPE) or not? The observation process lasted one month, during which twenty four (24) observations were collected on observation grid designed for the purpose.

3 Results

3.1 Diagnosis Stage

The diagnosis results of electrocuting and burning risks in the workshop (Table 2) confirmed the presence of such hazards. In front of each risk situation, a proposed action to undertake is described, in order to alienate the hazardous situations as recommended by ILO/IEA [21].

3.2 Evaluation Stage

In order to determine the priority of action to undertake to prevent electrocuting and burning risks facing the workers of the workshop, five parameters have to be measured, according to MADS method [22], these were: (1) the frequency of exposure to risks, (2) the level of severity 'LS', (3) the dose of exposure to risks, (4) the level of exposure to risk 'LE', and (5) the level of risk it self. Measurement results of these parameters are presented along the following pages.

3.2.1 Frequency of Exposure to Risks

Three categories of exposure to risks were sorted out by the evaluation team, namely: (1) a permanent exposure to risk, when the worker was exposed once a week, (2) a frequent exposure to risk, when the worker was exposed once a month, and (3) a rare exposure to risk, when the worker was exposed once a year. Results (Table 3) revealed that four out of six experts (66.66%) rated the exposure to electrocution and burning risks in the permanent category, as the workers of the shop floor were dealing with electrical hazardous situations at least once a week.

3.2.2 Level of Risk Detection (LR)

Was either at simple level, when the risk can be visually detected, or at complex level, when the detection of the risk needs depth analysis and necessary equipment to unveil its source and consequences. Results (Table 3) revealed that four out of six experts (66.66%) estimated the detection level as a complex operation, because most of the electrical malfunctions require in-depth analysis and use of appropriate detection equipment by qualified personal. While, two experts (33.33%) estimated that the detection of electrical hazards in the work shop floor under investigation could be done visually.

3.2.3 Level of Severity (LS)

This is the level of seriousness of the electrocution/burning risk which was evaluated on a five point scale, from a first level of severity (LS1) "a slight impact on health" to the fifth level of severity (LS5) "fatal accident". When asked to rate the level of electrocution risks facing the workers of the shop floor, experts' estimations were spread along the rating scale, from "a slight impact on health" to "fatal accident" with a tendency towards "serious impact" and "fatal accident" (Table 3).

Table 3. Shows the results of the frequency of exposure to risk, level of risk detection and the level of severity of the risk as estimated by the experts (n = 6).

	Frequency of Exposure to risk			Level of risk detection		Level of severity (LS)					Total
	Rare	Frequent	Permanent	simple	Complex	LS1	LS2	LS3	LS4	LS5	
Evaluation frequency	1	1	4	2	4	1	1	1	2	1	**6**
%	16.66	16.66	66.66	33.33	66.66	16.66	16.66	16.66	33.33	16.66	**100**

3.2.4 Risk Increasing Factors

These factors where estimated by the experts team on a worksheet, indicating in front of each factor the answer (yes/no) they think was the correct estimation. Results of experts are shown in Table 4. In the absence of training records and professional skills of the workers of the shop floor, experts of the evaluation team, as they were acquainted with the personal of the work shop floor, were addressed to evaluate the training level of the workers to deal with electrical equipment and electrical tasks, 83.34% of the responders agreed that the workers were not trained enough to perform the tasks in question. When asked to evaluate the impact of physical working conditions on the workers, nearly all the experts agreed on the negative impact of the physical work conditions. This results was in agreement with the inadequate values recorded by researchers during the period of the field study. The night work, as a risk increasing factor was totally absent in the present case study, the work was done during the day hours.

Table 4. Shows the results of risk increasing factors as estimated by the experts (n = 6)

Risk increasing factors	% of experts estimation	
	Yes	No
Do you think the workers are well trained to perform their work?	16.66%	83.34
Do you think level of noise in the workshop has negative impact on workers?	00%	100%
Do you think the range of temperature in the workshop has negative impact on workers?	00%	100%
Do you think level of humidity in the workshop has negative impact on workers?	33.34	66.66
Do you think the level of luminosity in the workshop has negative impact on workers?	16.66%	83.34
Are workers working at night?	00%	100%

Table 5. Shows the evaluation grid of the dose of exposure to risks.

No	Parameters of exposure dose	Low dose DE1	High dose DE2
01	Time of exposure to the risk	Short period	Long period
02	Number of worker exposed to risk	Small	Large
03	Trained/untrained worker force	Trained	Untrained
04	Protection equipments	Used	Not used
05	Increasing factors: physical working conditions/night work	Exist	Not exist
06	Level of risk detection	Simple (visual detection)	Complex (depth analysis)
Total	–	–	

3.2.5 The Dose of Exposure to Risks (DE)

Was determined from the following six parameters:

- Time of exposure to the risk (short period: less than 50% of working time, long period: more than 50%),
- Number of workers exposed to risk (small: two workers and less, large: more than two workers),
- Trained/untrained workforce,
- Protection equipments (used/not used),
- Existence of Increasing factors: physical working conditions/night work,
- Level of risk detection (simple: visual detection/complex: in-depth analysis).

Five parameters of exposure dose out of six, were rated by experts of the evaluation team in the high zone dose. Although, the exposure to the risk was for short periods during working hours, all the other factors were in favour of a high dose of exposure, as the workers were untrained to deal with situations involving electrical duties and equipment, the personal protecting equipment were not used, the risk detection was a complex operation that needs appropriate equipment and expertise, beside the presence of bad physical working conditions as risk's increasing factors.

3.2.6 Level of Exposure to Risk (LE)

Is the combination of both the frequency and the dose of exposure to risk. The level of exposure has been divided into three categories: low, moderate and high level, as shown in Table 7.

As shown in the Table 7, the results of the present study revealed a high level of exposure to risks. This was a result of the combination of:

1. The frequency of exposure to risks which was a permanent exposure (once a week) as evaluated by 66.66% of experts of the present study (Table 3) and,
2. The dose of exposure which was a high dose, accumulating five parameters (Table 6): (1) all the workers of the shop floor were exposed, (2) untrained workforce, (3) personal protective equipment unused and/or do not exist, (4) beside the presence of risk increasing factors like, bad physical working conditions, (5) the level of the risk detection was estimated as a complex operation, which needs an expert's intervention and an in-depth analysis.

Table 6. Shows the evaluation results of the dose of exposure to risks among workers of the shop floor (n = 38), as estimated by the experts (n = 6).

No	Parameters of exposure dose	Low dose DE1	High dose DE2
01	Time of exposure to the risk	✓	
02	Number of workers		✓
03	Trained/untrained workforce		✓
04	Protection equipments		✓
05	Increasing factors: physical working conditions & night work		✓
06	Level of risk detection		✓
Total		=**1**	=**5**

Table 7. Matrix of level of exposure to risks as evaluated by experts (n = 6).

	Frequency of exposure to risks		
	Rare (F1)	Frequent (F2)	Permanent (F3)
Low dose of exposure to risk (DE1)	Low	Moderate	Moderate
High dose of exposure to risk (DE2)	Low	Moderate	High

3.2.7 Level of Risk (LR)

Is the fifth and last parameter of the evaluation process of the MADS method. According to the value of this parameter, the appropriate action will be taken. the level of risk was calculated from two parameters: (i) level of exposure (LE) and (ii) level of severity (LS), as shown Table 8.

The results presented in matrix Table 8, revealed that the level of electrocution risk was estimated as urgent, requiring a third priority of action (P3), corresponding to a collective protection strategy, according to MADS methodology.

Table 8. Priority of action to undertake for levels of exposure and levels severity of risk.

Level of exposure (LE)	Level of severity (LS)				
	LS1	LS2	LS3	LS4	LS5
Low (LE1)	LR5(P5)	LR4(P4)	LR4(P4)	LR2(P2)	LR1(P1)
Moderate (LE2)	LR5(P5)	LR4(P4)	LR3(P3)	LR2(P2)	LR1(P1)
High (LE3)	LR4(P4)	LR4(P4)	LR3(P3)	LR1(P1)	LR1(P1)

Where:
1. The first level of risk (LR1): catastrophic, requires a first priority of action (P1)
2. The second level of risk (LR2): critical, requires a second priority of action (P2)
3. The third level of risk (LR3): urgent, which requires a third priority of action (P3)
4. The fourth level of risk (LR4): dangerous, which requires a forth priority of action (P4)
5. The fifth level of risk (LR5): acceptable, which requires a fifth priority of action (P5)

and:

Positive work zone that requires personnel protection
Collective protection zone
Elimination of risk at source zone

4 Discussion

The results of the present study have revealed a permanent presence of electrocuting and burning risks in the work shop floor of railway concrete sleepers, as shown in Table 2, this conclusion is the outcome of the eight items of ergonomics checklist [9], which were used, in order to detect the presence/absence of electrocution/burns in the work place. All ingredients of electrocution, burning and fire catching were present in the work shop floor of the present study, like the use of unsafe power tools with no proper insulation, unsafe wiring connections for equipment and lights, with no easy access to first-aid equipment and primary health-care facilities, etc.

These are common practices in many industrially developing countries, as has been pointed out in different studies, and among many occupational groups [12, 13], Attempts to explain such phenomenon are multiples, some of them refer to cultural explanations, like the naivety in dealing with hazards [24], or perceptions of experience with risks [25], others refer to the lack of the necessary training in dealing with electrical equipment, lack of safety culture and non-compliance with occupational safety and Health regulations [26].

Although the phenomenon of carelessness and acceptability or tolerability of a risk in dealing with hazardous situation is still enigmatic [26], the results of the present study cannot go beyond the evaluation and assessment of electrocuting and burning hazards, as the explanation of the situation needs in depth studies.

The frequency of exposure to risks (FE) was estimated by 66.6% of experts (Table 3) of this study as a permanent risk (once a week). The dose of exposure to risks, as a further step in our analysis can bring more light on the situation. Although, the workers of the present study dealt with hazardous situations for short periods of time (Table 6), the large number of untrained workers exposed to such a risk, and the non use of personal protective equipment, made the dose of exposure bigger than expected from the frequency of exposure rating, particularly in the presence of risk increasing factors, like: bad physical working conditions. All these factors, beside the complexity of risk detection, as it needs in depth analysis and experts' intervention, gave us a high dose of exposure to electrocution and burning hazards (Table 6). These results pinpoint the high level of exposure (Table 7). When experts were asked to rate the present level of severity on a five points scale from: "a slight impact on health" to "fatal accident", the evaluation results spread along the five points of the scale, with a tendency towards "serious impact" and "fatal accident" (Table 3). This tendency is the result of a number of factors like:

1. The design of the workshop itself, which does not respond to the standards of occupational safety, making workers close to the electrical connections, and thus become more susceptible to electrocution hazards.
2. The lack of awareness among workers and managers, alike, of the dangers caused by the non-respect of the safety standards of equipment and facilities, and their regular maintenance.
3. Health and safety programs are especially weak or totally absent, for aspects dealing with electrical hazards, as their detection needs in depth analysis and experts' intervention.

By identifying the priority level, the present study recommended that "a collective protection strategy" is the appropriate action to take, in order to prevent this category of risks. The collective protection strategy should be implemented, through an effective electrical safety program, which "embraces multiple strategies that seem to have the best chance to eliminate injury" [27]. Safety program is a collective action, is based on collaborative ergonomics solutions which as has been advocated by many ergonomists as "participatory ergonomics program" [28–31].

The study revealed the following results: (1) a constant frequency of electrocuting and burning risk facing the workers of workshop; (2) a strong dose of exposure to risks (3) a high level of exposure to risks (4) the risk of electrifying and burning has a serious impact, but without complications; (5) the level of seriousness calls for rapid intervention.

5 Conclusion

Despite the many regulations and laws concerning the different risks at the work place in general, and electrocution, burning and fire catching in particular, the situation of safety is still alarming in the Algerian industrial sector.

It is essential to find the right combination of rules, believes, attitudes, and good practices, which will create a positive safety culture at workplace in the Algerian industrial sector. Such a combination seems to be a very challenging exercise to policy makers, government departments, managers, trade unions and workers at the shop floor level.

By identifying the priority action to prevent electrocution and burning risks, the present study is clearly advocating for a participatory ergonomics approach, as it concerns all the stakeholders of the work place.

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Development of Child Climbing Behavior Video Database

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Abstract. Climbing is an important fundamental skill that children acquire in early childhood. Children love to climb everything, including consumer products, such as furniture, that are not designed to be climbed on. This puts children at risk of severe injuries. To prevent injuries, it is critical to understand how children climb on objects. The purpose of this study is to collect children's climbing behavior data to clarify the relationship between climbing behavior and object features.

Keywords: Child injury · Furniture tip-over · Climbing behavior · Database

1 Introduction

Climbing is an important fundamental skill that children acquire in early childhood. Children love to climb everything, including consumer products, such as furniture, that are not designed to be climbed on. This puts children at risk of severe injuries. According to a report from the U.S. Consumer Product Safety Commission (CPSC), on average, every 30 min tipped furniture or a falling TV sends an injured child to the emergency room in the United States [1], one and two-year-olds account for most of furniture-related injuries, 2,000 and 1,700 injuries annually based on CPSC estimation, respectively [2]. Adult supervision as a major contributor of child injury prevention is controversial [3], but injuries can occur even with adult supervision. It is crucial to create safe environment which allows children to take risks and challenge their potentials.

Recently, research on injury prevention using advanced technologies has started. Kakara et al. developed the child behavior measuring system using 12 video cameras and the bluetooth-compatible acceleration-gyro sensor attached to a child and analyzed injury risk due to falls [4]. They used the body trunk's motion data to conduct a realistic biomechanical simulation and to assess injury risks. In the field of elderly care, Robinovich et al. installed cameras in long-term care facilities and collected 227 fall data from 130 people over nearly three years. By analyzing fall video data, they revealed that the most common cause of falls was incorrect weight shifting, followed by a trip or stumble, hit or bump, loss of support, and collapse [5].

Winston, Puzino, and Romer, the world's leading researchers in the field of injury prevention, called for a shift from "one-size-fits-all" or universal strategies to "tiered risk strategies" to achieve precision prevention [6]. Utilizing advanced technologies and

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understanding people's behaviors are a promising approach to precision prevention. The research utilizing these technologies will surely advance the injury prevention research field forward.

The purpose of this study is to collect children's climbing behavioral data to clarify the relationship between climbing behavior and object features. Although anchoring furniture is a recommended action that parents and caregivers should take to protect children from serious injuries and deaths, designing safer and more stable furniture is necessary because it would not require one's preventive action. Also, collecting children's climbing behavioral data and understanding how children climb on objects makes it possible to conduct precision prevention for furniture tip-over injuries.

2 Methods

We did an observational study between February 6, 2017, and February 19, 2017 in Tokyo, Japan. A climbing apparatus measuring 158 cm W × 112 cm D × 97 cm H was constructed from a common Japanese children's product which consists of ø3 cm smooth, rigid, cardboard tubing and plastic connectors. Figure 1 shows a picture of the area where our study was conducted and the climbing apparatus. The apparatus includes 7 different climbing features (Fig. 2).

Fig. 1. A climbing apparatus used

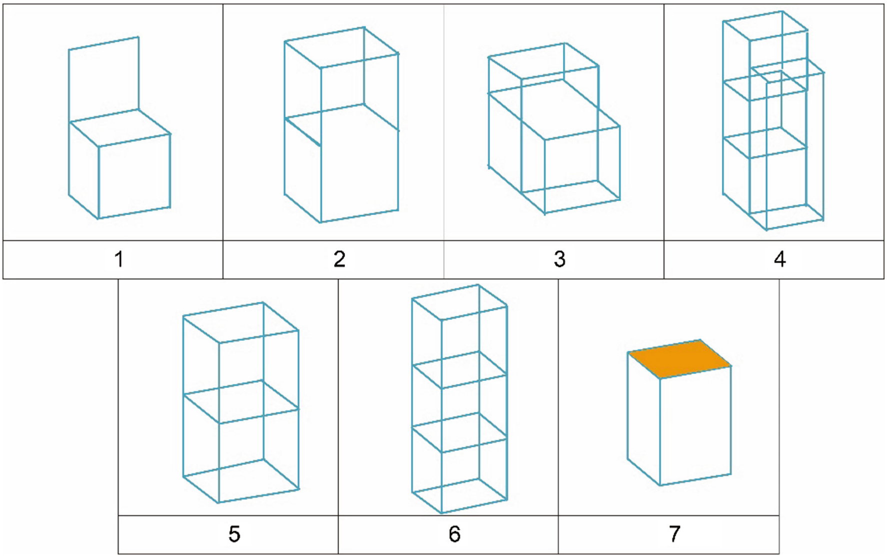

Fig. 2. Seven types of climbing feature

Fig. 3. Snapshots of the experiments in progress

On the day of the experiment, we asked a parent their child's age and height, then measured the child's weight with a weighing scale. Children were asked to play with the apparatus as long as they wanted. Most children repeated cycles of playing with the apparatus and taking a break. Two RGB-D cameras (Microsoft's Kinect) were used to record the children's interactions with the various climbing features. Snapshots of the experiments in progress are shown in Fig. 3.

After we conducted all the experiments, we analyzed the video for climbing patterns and developed a database consisting of age, climbing patterns, object features and videos.

3 Results

Fourteen children ages 12 to 58 months participated in this study. We recorded data for 249 observations of climbing behavior. We observed 8 climbing behavior patterns; how children use their appendages to interact with various climbing features to support their weight (Fig. 4). Based on our analysis, older children use strategies that involve less body contact with the climbing apparatus. We developed a climbing strategy map to show the relationship between age and climbing strategies used. An example of the climbing strategy map is shown in Fig. 5. Then, we linked it to a video library. When you click each icon on the map, you will obtain a video which shows a child using a particular climbing behavior on a specific climbing feature (Fig. 6).

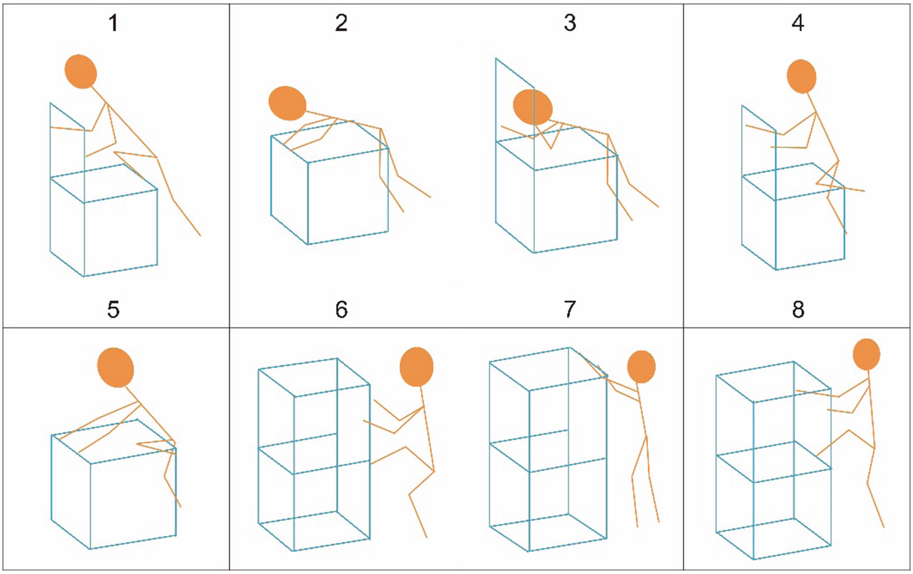

Fig. 4. Observed climbing behavior patterns

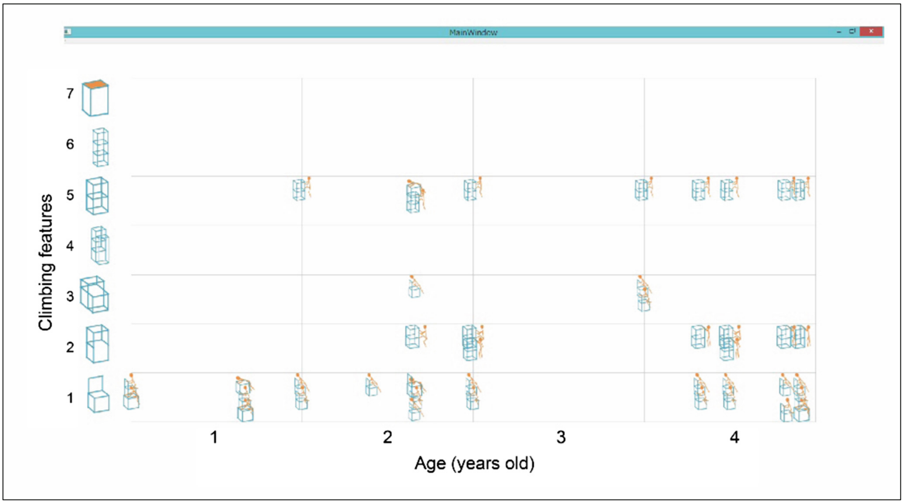

Fig. 5. An example of the climbing strategy map

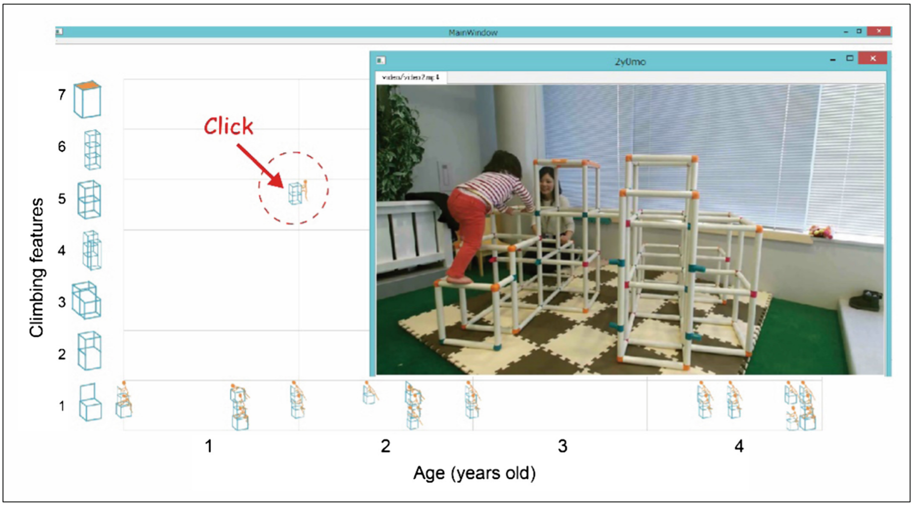

Fig. 6. An example of the video database

4 Discussion

Our results show the relationship between age and climbing strategies used. We also observed 8 different climbing strategy patterns in this study. By analyzing climbing behavior data, we see how children use their body parts to interact with the climbing apparatus based on their age. As we mentioned previously, one and two-year-olds account for most of furniture-related injuries. Understanding climbing behaviors based on age and actual climbing footage will help manufacturers improve the safety of their consumer products. Our results also suggest that we can scientifically analyze children's climbing behavior and that being able to determine its patterns will lead to developing more powerful prevention approaches.

The study faced some important limitations that should be noted. First, we believe that children's climbing patterns will vary and the number of the patterns will increase as conditions of the apparatus change. For instance, the apparatus used in this study was made of smooth, rigid, cardboard tubing, which children can comfortably touch with their hands and feet. When children try to climb objects which have a rough surface or an edge similar to that of a dresser drawer, their climbing patterns will change. Also, the shape of a climbing object will significantly affect how children interact with the object. If a climbing object consists of cuboid, children cannot climb the same as a jungle gym. We hope to investigate what environmental factors influences children's climbing behaviors in the future.

We consider our results as a fundamental component for precision prevention for furniture tip-over injuries. In this paper, we discussed the relationship between objective features and climbing patterns based on age. Since we used Kinect sensors, climbing posture data were also recorded. We can use these data to determine the center of gravity, and calculate the amount of force applied to a target object. Then, we can conduct a simulation to assess the injury risk of furniture tip-over. Further research is needed to apply children's climbing behavior data to designing tip resistant furniture.

5 Conclusion

We observed 14 children's climbing behaviors using 2 RGB-D sensors and recorded the children's interactions with various climbing features. In addition, we developed the climbing strategy map linked to a video library. We understand the relationship between climbing behavior and object features within an age group. In future study, we will continue to gather climbing behavioral data, refine the map and hope to locate the child's center of gravity while climbing. Moreover, we hope to develop a simulation system to show the impact on an object and to apply the research results to new safety standards.

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STAMP Analysis of the Hanmi Short Selling Episode

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Abstract. The financial market has been evolving as an increasingly complex sociotechnical system, ever since it experienced expansion on account of information technology developments. Our approach is rooted in engineering-based accident analysis, or so-called systems-theoretic accident modeling and processes (STAMP). From the STAMP model, systems-theoretic process analysis (STPA) can be developed on the basis of the accident analysis method and hazard analysis. STPA attempts to systematically inspect accidents, and is involved in system redesigns that, had they been implemented, could have precluded those accidents. Through the lens of STPA, we aim to pinpoint the overarching causes of problems in the South Korean disclosure system and find more effective remedies. Having suspected Hanmi Pharmaceutical of being part of an insider trading scandal, South Korea's Financial Supervisory Service investigated that company. By applying the STAMP model, we derive more insightful recommendations regarding the timely disclosure of company information, and thus the prevention of suspicious (and possibly illegal) short selling in the stock market.

Keywords: STAMP · Disclosure · Short selling

1 Introduction

The financial market has been evolving as an increasingly complex sociotechnical system. Financial systems benefit from interacting extensively with various disciplines, including not only social but also scientific fields [1]. The extent of such benefits is contingent upon having a good understanding of many recurring failures in financial markets. Financial crises have been witnessed in many economies for quite some time. Previous studies on financial crises mostly performed data analysis by using traditional economic models or variants thereof; typically, in such studies, a specific economic model is built as a set of equations, and quite frequently is rendered insolvable through the use of further equations. Practically, problems in the financial market tend to involve various components and thus are not easily explained only by mathematical

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modelling. Recently, a considerable body of engineering literature has suggested the use of systems-theoretic accident models and processes (STAMP) as a methodology that leverages systemic interaction among individual components.

This study applies the STAMP approach to a recent occurrence of turbulence in the South Korean financial sector—namely, the aftermath of massive short selling. On September 30, 2016, the South Korean stock market witnessed the massive short selling of Hanmi Pharmaceutical stock [11]. The Financial Services Commission (FSC), South Korea's financial regulator, investigated whether institutional investors were aware of the termination of an anticancer drug license between Boehringer Ingelheim and Hanmi before the information was disclosed to the market. On the other hand, prosecutors failed to prove the culpability of Hanmi's corporate disclosure team, but did indict four individuals of the illegal use of information that had not been officially disclosed in the online disclosure system. In that sense, massive short selling is likely to be considered a case of misconduct involving individual investors, rather than a systemic problem on the part of the company.

Using the STAMP framework, this study aims to determine the possible causes of problematic short sales, and it suggests how to preclude similar problems [2, 7, 21]. Section 2 provides background information on the STAMP approach, and Sect. 3 analyzes the Hanmi short selling accident, by using the STAMP/systems-theoretic process analysis (STPA) method. Section 4 concludes.

2 Background Information and Literature Review

2.1 Proximate Events

In July 2015, Hanmi Pharmaceutical made a license-out contract with Boehringer Ingelheim; that contract enabled the export of technology used to develop lung cancer medicine. Immediately after disclosure of the news, Hanmi's stock price almost doubled, and remained above USD 600. However, that contract—valued at USD 7.7 billion—was terminated as of September 30, 2016, and news of that cancellation was released to the stock market at 09:28 on September 30. Curiously, short sales of 50,471 Hanmi shares occurred in the 28 min between when the market opened (at 09:00) and the time of Hanmi's posting on the Data Analysis, Retrieval and Transfer System (DART) system. The amount of short sales occurring immediately before the disclosure constituted almost one-half of all short sales made that day; additionally, the entire volume of short selling made that day was almost 20 times the average volume seen by Hanmi.

Figures 1 and 2 provide some information regarding trends in the trade of Hanmi Pharmaceutical stock.

Such an unusually large amount of short selling was suspected of being indicative of insider information trading, and thus came under investigation by the FSC and prosecutors. The relevant studies include [2–4, 6, 10].

Our approach is rooted in engineering-based accident analysis, or so-called STAMP; it includes mechanical or human elements that span all the contextual and organizational components of complicated sociotechnical systems. [13].

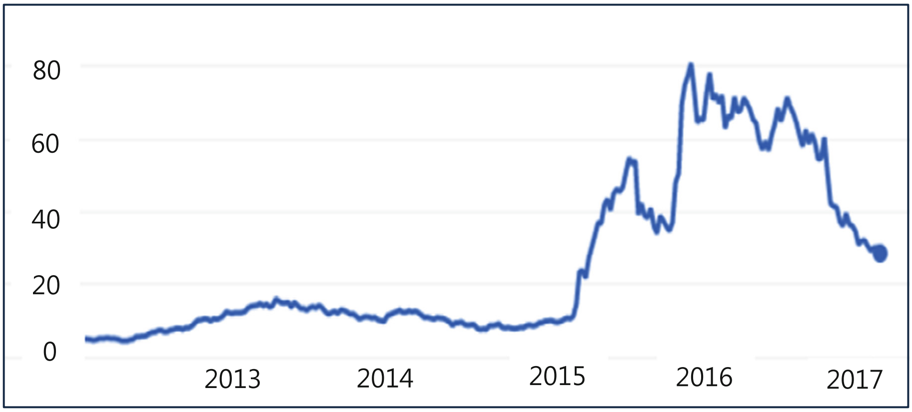

Fig. 1. Stock price of Hanmi Pharmaceutical

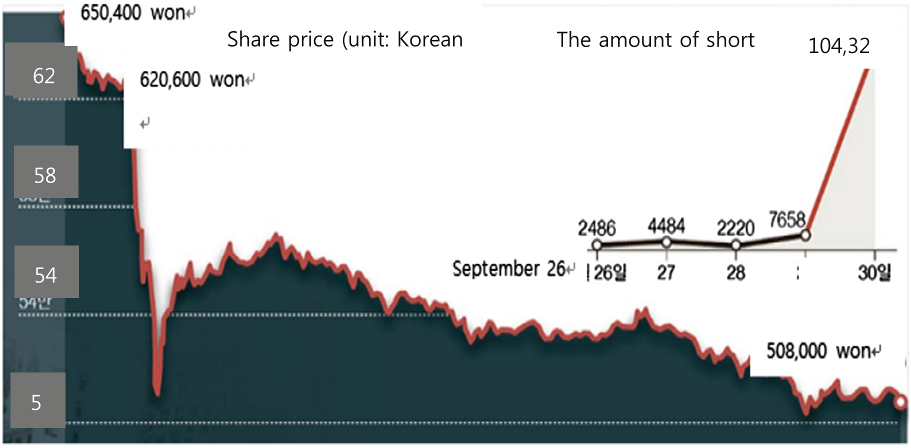

Fig. 2. Short selling of Hanmi Pharmaceutical

The STAMP model views accidents as an outcome of inappropriate interactions among system components, rather than as problems that stem from individual components. As Leveson points out, major accidents usually derive from unsafe behavior and interaction involving various components in the control structure [15] (Reliability Engineering and System Safety 136, 2015, 17–34).

The need in South Korea for a unified financial supervisory body arose from the Asian financial crisis. The FSC was launched in 2008, when the Financial Supervisory Commission merged with the Financial Policy Bureau of the Ministry of Finance and Economy. Using statutory mandates to draft and amend financial laws and regulations, the FSC supervises financial institutions, issues regulatory licenses, and monitors foreign currency markets. The FSC integrates the financial supervisory functions of the Ministry of Finance and Economy (currently the Ministry of Strategy and Finance) and the Bank of Korea. Additionally, it provides direction and guidance for the Financial Supervisory Service (FSS), which examines and investigates financial institutions [9].

The FSS was launched by virtue of the Act on the Establishment of Financial Supervisory Organizations, in 1997; it was given the authority to supervise, in an integrated manner, the four financial sectors (i.e., banking, securities, insurance, and credit management funds) that were once under the auspices of the Finance Ministry.

The FSC and FSS conform to the two-tier supervisory system for financial institutions in Korea. Principally, the FSS is in charge of capital market supervision, financial consumer protection, and other oversight and enforcement activities, under the guidance of the FSC. On the other hand, the FSC is responsible for amending rules and approving licenses that relate to establishing financial institutions. As a government regulator, the FSC is staffed by civil servants, while the FSS—as a specially legislated supervisory authority—is staffed by private sector employees.

3 Analysis of the Hanmi Short Selling Episode

The use of systems-theoretic tools can be enormously beneficial to considering any sort of organizational question, whether in reference to physical or intangible factors. However, most use of STAMP approach has been made to accidents involving physical components [15, 16, 19].

Traditional perspectives—such as chain of events—tend to misunderstand the relationship between safety and reliability [13, 15] states that safety is an emergent property of the system; however, reliability is a characteristic of individual components. The systems-theoretic view of safety conceptualizes system safety as a control problem. Many discussions with respect to modern accidents touch upon issues with component interaction in sociotechnical systems. [5, 8].

STAMP is a model used to analyze the causal relationships among the elements involved in an accident. STAMP analyzes individuals not considered by the techniques inherent in models that are based on chain of events and various sociotechnical elements [13].

STAMP consists of three basic concepts—namely, safety constraints, the hierarchical safety control structure, and the process model [13–15]. Safety constraints constitute a basic STAMP concept. Accidents occur wherever there is insufficient control of system operations. System safety is obtained by securing appropriate controls at each level seen in Fig. 3. Hierarchical structures, meanwhile, determine controls and procedures: higher levels determine controls, procedures, policies, and the like, while lower levels actually derive from those controls, procedures, and policies. The third concept, the process model, includes the controller and the controlled process used to represent hierarchical control structures for systems and accidents. The controller sends a control action and feedback to the controller, through the controlled process.

STPA is a new safety analysis technique that analyzes the STAMP accident model [17, 18, 20]. Even where there is no error in the system or in the system elements themselves, risk factors that stem from interactions among elements can be removed. Especially in terms of analyzing risk factors, STPA has features that differ from those

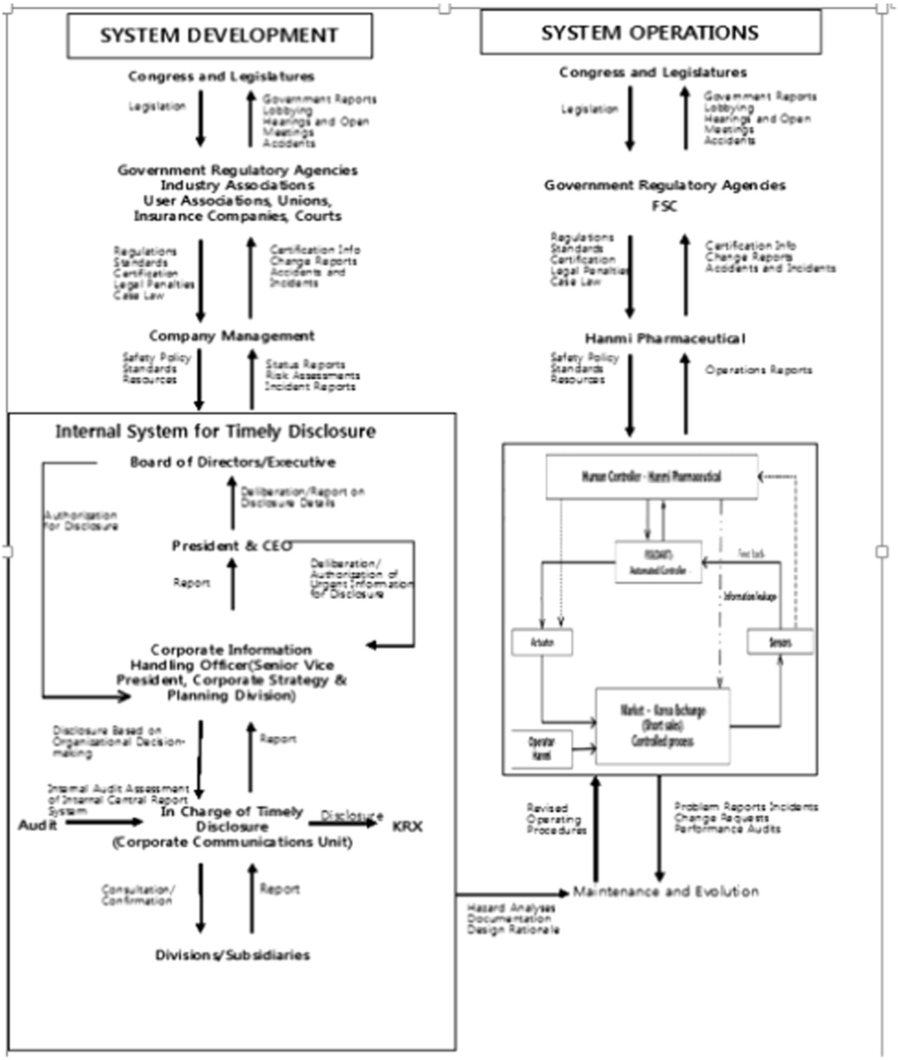

Fig. 3. Phase 1: Set the risk and safety constraints of the system

in the traditional methods; these include hardware, software, people, and organization. After analyzing systems by using the STAMP model, STPA can be used to pinpoint unsafe control actions that could lead to accidents, and it analyzes their causes [15]. STPA performs safety analysis in four steps, as follows [15].

Phase 1. Set the risk and safety constraints of the system
Phase 2. Derive the control structure of the system (construction)
Phase 3. STPA step 1: Identify unsafe control actions that may be system risk factors
Phase 4. STPA step 2: Identify the potential cause of inappropriate controls, as pinpointed by STPA

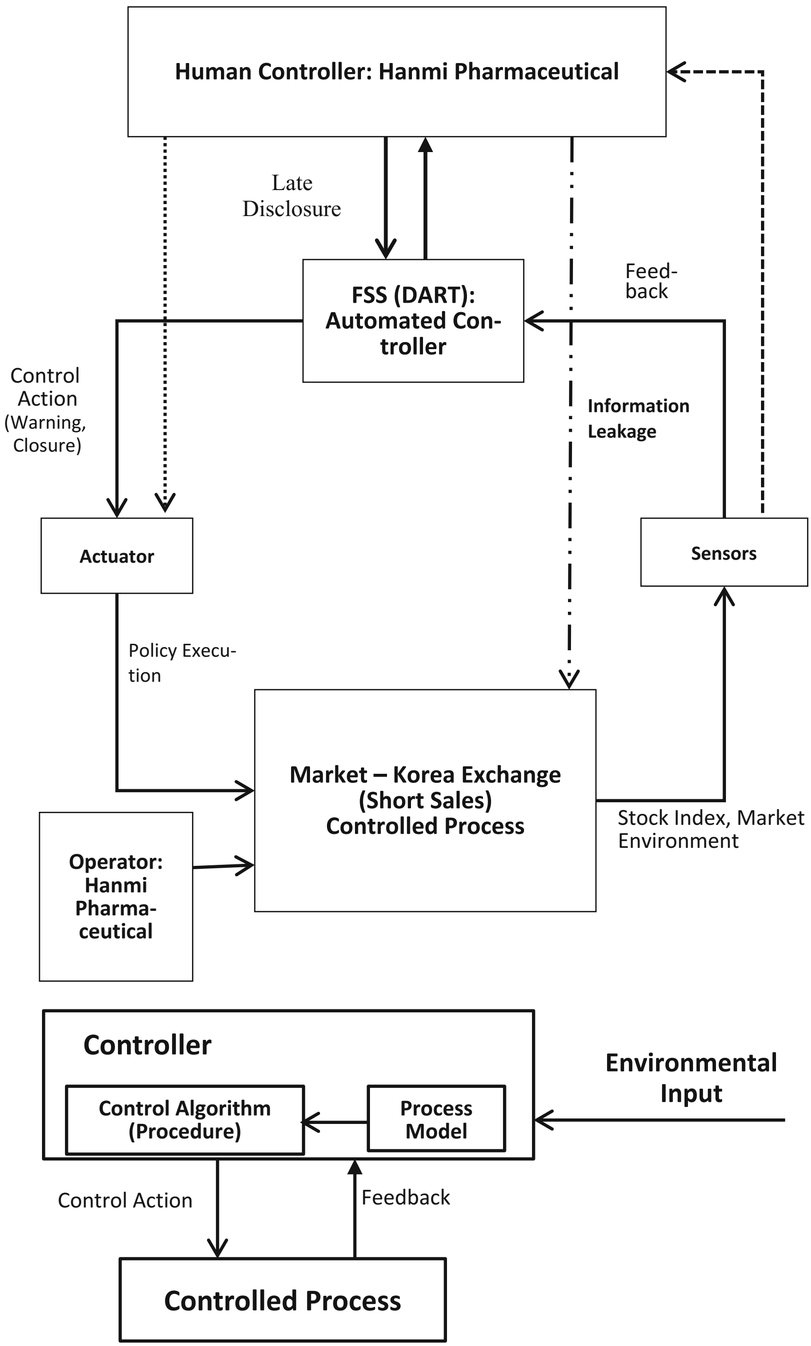

Fig. 4. Phase 2: Derive the control structure of the system (construction)

To perform STPA, the risk and safety constraints of the system are defined as per the procedures ordered above, and the control structure is identified. When one's understanding of the control structure is complete, the first step in the STPA is to determine the inappropriate controls that create risk; these inappropriate controls are classified as per the typology depicted in Fig. 3.

In collaboration with the FSC, the FSS supervises South Korea's corporate disclosure system. As shown in Fig. 4, the FSS is South Korea's integrated financial regulator, and it examines and supervises financial institutions under the broad oversight of the FSC, the government regulatory authority. The FSS is responsible for listed companies with regards to their disclosure of corporate information on operational and financial activities. To facilitate a more timely disclosure process, the FSS's automated and online disclosure system (i.e., DART) needs to be systematically redesigned.

Fig. 5 shows that many countries control their short selling by means of financial regulations. Once we have identified these four key controls, we look for the possible sources of those controls. After analyzing the causes and identifying possible scenarios in Table 1, they are removed.

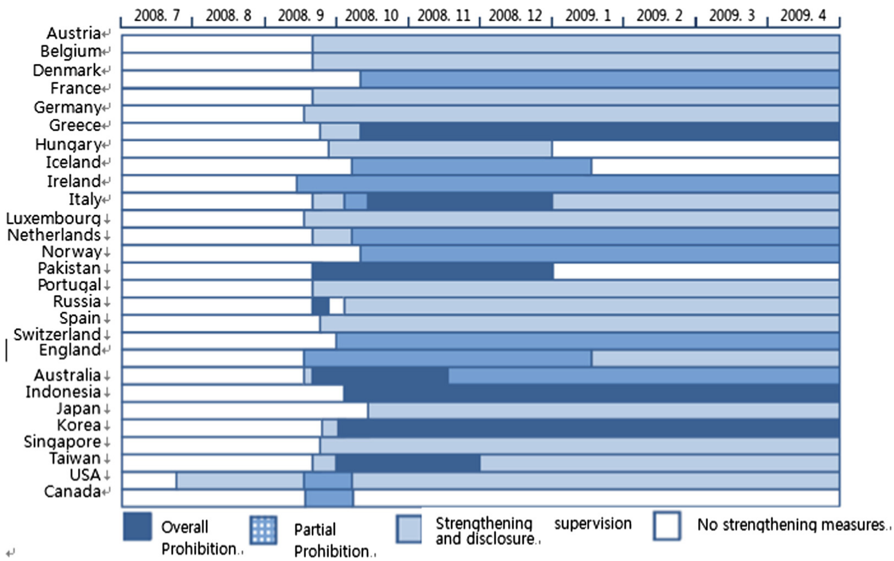

Fig. 5. Degree of control measures on short selling in various countries worldwide

Phase 3. STPA step 1: Identify unsafe control action that may be system risk factors

Having suspected that Hanmi Pharmaceutical was part of an insider trading scandal, the FSS focused its investigation on the company. The FSC investigated whether institutional investors were aware of the termination of the anticancer drug license between Boehringer Ingelheim and Hanmi before the news was disclosed. The South Korean financial regulator also unveiled a set of tougher measures with regards to short

Table 1. Improper control types

Type	Improper control types
Not providing	Short selling does not occur at the proper time, since the necessary information is not provided.
Providing causes	Short selling occurs inappropriately, since the provided information is inaccurate and/or incomplete.
(Provide) too late or too early	Short selling does not occur at the proper time, since necessary information is provided either too soon or too late.
(Stopped) too soon or (applied) too long	Short selling does not occur at the proper time, since necessary information is provided either too soon or too late.

selling and the overall disclosure system; through those measures, the FSC sought to prevent market volatility and enhance monitoring on possibly illegal transactions.

Phase 4. STPA step 2: Identify the potential cause of inappropriate controls, as pinpointed by STPA

Hanmi Pharmaceutical

Safety requirements violated:

· Failure to ensure that all required information is conveyed to the DART system as immediately as possible

· Failure to comply with rules and requirements regarding information security when the company's contract with Boehringer Ingelheim was terminated on September 30, 2016

· Newspaper said that some members of the disclosure team were suspected of leaking information on the contract termination through their personal channels, such as social network services.

Context

· Stock price of Hanmi Pharmaceutical had risen since concluding its contract with Boehringer Ingelheim in July 2015

· Hanmi Pharmaceutical had developed innovative technology for lung cancer remedies

· The company met all regulatory requirements in reporting its corporate information to the DART system

Inadequate control actions

· Allowed for information management of the disclosure team members

Process Model Flaws

· The company had assumed that all the disclosure team members were basically loyal to the rules dictated by the DART system

DART (Data Analysis, Retrieval and Transfer System)

Safety requirements violated:

· Not available

Context

· Technically, there are no problems with disclosing information, once it has been reported to the DART system

Inadequate control actions

· Absence of warning of the possibility that some information leakage had taken place prior to information disclosure

Process Model Flaws

· The system assumes that all corporate information is conveyed to the DART system without any predisclosure leakage

4 Conclusion

By applying the STAMP model, we can derive some meaningful recommendations regarding the timely disclosure of company information, and thus possibly prevent suspicious and/or illegal short selling on the stock market. Financial market participants, practitioners, and policy-makers have too much confidence in the DART system. The FSS, as a private sector employee, should be a sophisticated supervisory system; however, the system's weak points were revealed upon making investigations into the short selling of Hanmi Pharmaceutical.

A possible lesson from this case of massive short selling is that such a problem is not a consequence of failure among particular components, but rather involves the complex interactions among system components. Therefore, detecting a specific component failure may not contribute meaningfully to accident analysis. A systemic approach to such analysis allows for more fundamental remedies to financial market problems.

The main problem with short selling is overconfidence. The role of short selling in the market is nothing wicked—on the contrary, it is a highly efficient form of economic and social organization—but it is vulnerable to panic. The results of STPA suggest that the disclosure system should be redesigned to prevent information leakage.

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An Epidemiological Perspective of Individual and Population Health Risk Prevention

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Abstract. Several distinct but intrinsically related sections are discussed from an epidemiological standpoint including the epidemiology of risks, individual versus population risks, intervention and prevention. A number of specific risk factors identified in published research are considered and categorized for either individual or population-level effect. Risk factor assessment, with an emphasis on the concept of risk level among individuals through their life span is specified, with a focus on consumption patterns. The efficacy of prevention is evaluated among intervention approaches, with case studies provided for context.

Keywords: Epidemiology · Individual · Risk · Population · Prevention · Health literacy · Human factors

1 Introduction

The terms ‘individual level’ and ‘population level’ are used to distinguish between two fundamentally different concepts: individual level refers to considerations which can be applied to a single individual, whereas population level refers to the aggregate data developed from the study of multiple individuals sharing some elemental similarity by which the population is identified.

1.1 Risk Factors and Causality

Due to the low overall percent of a given population, which will display abnormally high risk factors, there is low efficacy for reducing the overall occurrence of an affliction resulting from individual interventions based on developed risk profiles. This is because a majority of the population which develops a condition will not necessarily display a high level of the known risk factors to be related to the affliction.

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2 Individuals Versus Population Risks

While most risk factors – including gender, disability, education, and primary language fluency – can be evaluated as distinct among individuals of a population, some factors are better suited for investigation solely on the level of the population they affect. These factors are associated with increased risk levels across an affected population, including socioeconomic status and geographical location. Age, can be placed in both categories, and will be discussed twice in this section.

2.1 Risk Factors of Individuals

Risk factors on an individual level can be defined as behaviors or inherent characteristics distinct among members of a population but commonly associated with their status of risk. These factors may be evaluated as aggregate data, but their impact will be measured as a percentage of individuals that are affected by a given risk. In contrast to population risk, individual risk level is determined by the sum total of an individual's risk factors, elements that don't impact wide swaths of the population at a time: age, gender, disability, education and language fluency.

Age. Age is the single factor guaranteed to change throughout the lifespan, altering the risk profile dramatically as individual's progress through established categories. An infant will have different risks than a child, an adolescent, an adult, and a senior [1]. Infants experience perhaps the greatest amount of passive risk. They are exposed to risk factors that they are unable to either encounter or avoid on their own. They are especially sensitive to environmental risks such as second-hand smoke or strangulation by normally benign household objects, which they are unable to avoid independently. Although their overall health has not yet had time to deteriorate, infants are also uniquely at risk for Sudden Infant Death Syndrome (SIDS) and various risks associated with premature birth.

As they mature, children develop more self-sufficiency. During childhood, more risk factors impact them due to their uninformed choices regarding risk. This requires investigation into the differences of risk perception by age group. Adolescents in particular are described as experiencing increased risk associated with social factors [2] which may be related to their continuing social development or desire to feel socially accepted. A challenge in the study of risk perception using a psychometric scale is that it is difficult to gather objective data. A 1995 study of the differences in risk-perception between adolescents and adults found teenagers to be less optimistic of avoiding injury than their parents, with their level of optimism decreasing proportionally to their increasing risk of injury [3].

Seniors may be evaluated as a distinct group. Compared to other age groups, they display increased health risks from traumatic injuries and illnesses. However, they also show a greater suspicion of novel health treatments and associated greater resistance to trying such measures [4], as well as an inaccurate perception of their own risk [5].

Adults that are not yet seniors are considered only briefly in this section, as they are the general population by which a baseline standard of risk is established for most consumer products. This can be evaluated in relation to adults as a 'target audience' of sorts, in which the population receiving information – be it advertisements or warnings – is a member of this age group and most likely to comply with warnings. While an adolescent may ignore a warning, a child will likely not have the means to purchase a potentially dangerous product and is assumed to be protected from avoidable risks by adults. The senior population is also affected by this phenomenon; a senior at high risk is expected to have a caretaker who can assist in the avoidance of risks.

Gender. From a behavioral standpoint, females have been shown to be more risk averse than males; when presented with decisions involving risk for a potential future gain, females have been shown to both overestimate the probability of a negative outcome and underestimate the potential long term benefits of taking such a risk. Males, conversely, appear inclined to overestimate the probability of positive outcomes as well as the potential benefits they may see. Some health risks are proving to be more behaviorally-related than intrinsically linked to gender [6]. The incidence of cardiovascular disease has traditionally been higher in men; however in recent years this gender gap is closing, in part due to women joining the workforce in higher numbers and progressing into higher stress positions. Other more acute health risks of injury and death, especially work-related, have traditionally been weighted towards the male population due to their disproportionately high representation in professions with an increased incidence of physical trauma, such as construction.

Disability. Individuals with disabilities may experience overall elevated levels of risk throughout their lives for a variety of reasons, many due to the characteristics of their disability. The most commonly cited definition of disability within the international community was developed by the World Health Organization in 1976, "a disability is any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being" [7]. The updated Disability Assessment Schedule (WHODAS 2.0) released in 2010 includes physical, mental and substance-use disorders [8]. Cognitive disabilities, while also present across a wide spectrum of severity, are considered separately from physical disabilities for a number of reasons. Cognitive impairment is more likely to have been present from birth, though some conditions are more associated with aging while others may develop in response to life events, and are more difficult to diagnose [9, 10]. Both categories of disability, however, show an increased prevalence in the senior population, developing as they age.

Education. Education can be considered influential in determining an individual's level of risk. While the primary effect of education is easy to observe – persons who are precognizant of a given risk will be better equipped to make decisions regarding their exposure to that risk – secondary effects are often overlooked. The direct effect of lower education is a lower baseline of knowledge of the information that is communicated in an academic environment. This affects individual health when such knowledge becomes related to consumer risk factors such as dangerous chemicals and equipment (see Fig. 1), and common activities associated with lowering risks such as reading labels or instructions to avoid product hazards or misuse. For example, a study of antimicrobial prescriptions found that 33% of physicians yielded to patient requests for antibiotics, while only 4.3% of specialists did so [11].

Fig. 1. Some warning labels may be difficult for users to comprehend and comply with.

Higher educated individuals have greater health literacy and are more likely to comprehend the context and meaning of standard risk communications, increasing their chances of understanding new encounters with risk information. Education may also be considered a type of language fluency, in which higher-educated people have the knowledge and means to understand the esoteric language used commonly in risk communications [12]. Limited health literacy impacts comprehension of patient safety information that accompanies pharmaceuticals (see Fig. 2), which can lead to failure to adhere to critical prescribing information, as well as understanding the risks [13].

Fig. 2. Patient safety information may be difficult for some individuals to comprehend, or read due to the small font (7-point on this label).

Language Fluency. Language fluency – as determined by the level of language an individual speaks in relation to the dominant language of the surrounding population – can impact risk factors and comprehension of risk communication. An example of this concept is the Hispanic population of the United States; there is an increase of over 10% in awareness of cigarette warning labels shown with high acculturation, including the adoption of the English language, in this population subset [14].

Manufacturers of consumer products may be compelled to address language fluency both due to an awareness of risk through consumer incidents and near-miss events. Failure-to-warn cases have succeeded by establishing company awareness of foreign language users of their product without placement of additional warnings written “in a way that communicates clearly and effectively with all of the relevant populations at risk,” a consideration that is inclusive of both the adequacy of translation and communication to illiterate users when necessary [15]. Internationally, there is no standard for the adequacy of translations. An appendix of the ANSI-Z535 standard provides translations of signal words [16].

2.2 Risk Variation Among Populations

In contrast to individual risk, population risk impacts members of a given population where and how it lives.

Socioeconomic Status. Socioeconomic Status (SES) impacts risk variation in a number of ways. Not only does SES directly affect the risks an individual is exposed to – as individuals of higher SES are exposed to different risks than those of lower SES – SES is often correlated with other population-level risk factors. Rural geographic areas are more commonly associated with low SES inhabitants, as are neighborhoods in large urban centers [17]. Low SES is associated with a myriad of problems which can increase the overall risk level, as well as several specific risk factors. Nutritional deficits are more common to people with low SES due to their inability to secure healthy food. Many crimes also are increased in low SES communities, perhaps even underestimated due to reluctance of many low SES populations to consult legal authorities, even when they may require protection [18]. High SES is also associated with risks, albeit of a different kind than those common to low SES. High SES populations are more likely to be exposed to foreign pathogens, as they travel more. There are also certain ‘luxury risks’ which are more common to high SES brackets – certain prohibited drugs are more commonly abused by wealthier individuals [19], and high SES is associated with the availability of certain high risk entertainment activities which are not available to less affluent individuals, such as sky diving, scuba diving and skiing.

Geographic Location. The geographic location of a population impacts the risk factors to which it is exposed by much the same function that socioeconomic status does: certain risk factors will be increased, reduced, or not be present in all populations because they are not unilaterally available across sectors. A comparison of urban and rural environments is used to illustrate this concept. It is important to note the differentiation of risk factors among geographical areas of countries and continents. For example, in a Moscow winter, warm clothing for cold weather is obligatory but optional in Central America. There is a tangible effect of overarching legislative themes on risk factors – the strict regulation of illicit drugs, for example, has a somewhat ironic correlation to the probability of death from those drugs which are banned [20–22]. From this data, it can be concluded that overall risk of drug overdose, whether from habitual abuse with a lack of legal options for support or one time exuberance and fear of repercussions if medical help is sought, increases in certain geographic locations where there may be legal consequences.

Rural geographic areas are associated with different risk factors than urban areas. While some highly urbanized, most likely low SES areas are associated with increased mortality and crime rates, they are reliably well maintained from a standpoint of modern convenience. Isolated rural areas, however, suffer from a lack of common modern conveniences such as reliable mobile phone coverage and internet connection. The travel time between rural areas and hospital-quality medical assistance, especially for conditions requiring a medical specialist, is a key factor. Rural areas are also associated with a separate set of risk factors – such as injury while using farm equipment not present in urban communities or hunting accidents. Rural areas may also lack water quality standards and have a higher incidence of illnesses from tap water, such as the isolated First Nation reserves in Canada [23].

Age. Age, previously discussed on an individual level, can also be addressed at the population level. While consideration of risk levels can be applied universally, certain populations are evaluated as a conglomerate rather than by differentiating among individuals. As a majority of citizens in high income countries are between the ages of 15 and 64, populations outside this range are most likely to be identified for special evaluation: children and seniors are of special note here [24]. Children are commonly subject to age-level restrictions in activities and product use. It is common to see labels indicating that products are not for use by children under a certain age and games that are designed for a minimum age. Products may also be subject to age-related precautions, such as legislation specifying that safety seats must be used for all car passengers below a given age or weight. On the other end of the age scale, seniors may have unique risk concerns. These are commonly health-related, such as guidelines established in the United States by the American Heart Association (AHA) and American College of Cardiology (ACC) recommending that adults over 75 take a moderate-intensity statin for primary prevention, even if they have no known cholesterol-related concerns [25]. They are also the target of a number of products and services designed around risk prevention and reduction, from walkers and canes for ambulation to medical alert devices and even home assistance for daily activities.

Culture. Culture may also impact risk in ways that are both expected and unforeseen. Cultures which place a greater emphasis on hygiene, for instance, will show lower microbial-related disease rates than those that focus on other issues. Minority cultures in a region are more likely to hold legislative authority in high suspicion, and will therefore show greater resistance to risk-lowering governmental action [14]. A family from a culture which traditionally values multigenerational households is less likely to respect regulations limiting the number of residents in small housing units. One instance of such unforeseen impact is described by the Dunning-Kruger effect [26], that people tend to incorrectly estimate their levels of competence towards a standard; higher performers on a variety of tasks tend to underestimate the results they will get, while low performers predict proportionally higher results for themselves. East Asian cultures, however, show an overall tendency to underestimate their performance, believing that poor results allow them greater opportunities for learning and improvement whereas Western subjects perceived these results as personal failings. From this study, it can be inferred that people's reaction to and perception of risk exposure will be, at least in part, defined by the culture in which they were predominantly raised.

3 How Risk Factors Change Over an Individual's Lifespan

It is important to note the dearth of characteristics which remain fully static throughout a lifespan. While some may be described as such – for a majority of individuals, gender and culture fall into this category – many more factors, both on individual and population levels change frequently as a people age. Even characteristics one would not expect to change progressively through our lifespan are less determined than expected. Language fluency is a prime example of such: all individuals are born without language fluency, and gain primary fluency through their guardians. The initial level of primary fluency may be increased or altered through schooling, social associations, or personal efforts. Similarly, secondary fluency is normally achieved by either personal or social pressures, as individuals expand their language base through academic or professional obligations, to fulfill a personal or familial goal for themselves, or to strengthen friendships across linguistic barriers. This presents difficulties in epidemiological study, as individuals' self-evaluation of their own fluency may not fulfill the criterion required for appropriate translation and interpretation of risk communications in their secondary language. Conversational fluency is not generally consistent with the level of comprehension required to interpret or communicate the technical jargon endemic to risk communications found on product labels [27].

4 Consumption Patterns: Discrepancies Among Populations

Consumption patterns are highly differentiated among different populations. Research observing the Finnish population indicates that some of the most influential factors determining consumption patterns are economic restraints, social regulation, conventions, routines, and socialization in peer groups. This is especially important when determining the discrepancies among easily differentiable populations, such as those divided by socio-economic and demographic factors, particularly gender, age, and income [28].

Products are generally marketed towards a target population to create positive feelings. This has been investigated thoroughly in recent years in the context of organic foods. For instance, when the developing market for organic foods was investigated in Croatia, it was determined that consumers overall, considered produce to be healthy and of high quality, and were more inclined to overlook detractors such as increased price [29]. However, the target market is not always determined by perceptions of quality or economy, as found in a study of energy drink consumption, marketed to young adults and college students of the mid-Atlantic United States. Results indicated that 51% of participants consumed energy drinks in relation to product function, citing reasons such as insufficient sleep (67%), to increase energy (65%), and to drink with alcohol (54%).

No significant reduction of use was associated with negative side-effects such as headaches or heart palpitations [30].

Consumption pattern differences are not limited to tangible goods. Insurance policies, intangible but undeniably a consumer product, can be used to exemplify both the discrepancies between population consumption patterns, and the way these differentials affect risk factors. Studies conducted in developing countries show limited insurance markets are stunted by moral hazard: a situation where there is an asymmetry in available information, a deficiency in the ability to enforce contracts, and an awareness that one party is protected against risk while the other incurs the costs should something go wrong. Populations without access to formal insurance, due to either geographic location or economic restraint, develop different behavioral patterns to mitigate the risk. For example, populations without access to insurance are more likely to choose occupations with a steady income, even if this income is lower than what they could earn through other less-secure jobs [31].

Risk factors associated with specific consumption patterns are not necessarily associated with a negative impact on overall consumption. Overt risks are exemplified by high-risk leisure sports, including skydiving, hang-gliding, climbing or BASE jumping. Participation in any of these activities increases individual risk for various severe physical injuries or death; however, few to none of the products marketed in association with these activities obscure or minimize apparent risks. These products advertise themselves as high risk, appealing to individuals' sense of excitement, adventure, and adrenaline to actively promote risk associated with consumption as a marketing device [32].

On the opposite end of the perceived risk spectrum is the risk of consuming some tap water. For example, in Canada, although 25% of individuals in a cross-Canadian study reported health concerns about tap water, less than 6% of households spent more than $50 annually on water sanitation, and 25% of households consume exclusively tap water. Research reports that consumers replace tap water due to flavor or odor while health concerns were considered only a minor issue, indicating a low awareness of health concerns; this effect holds even when considered in conjunction with the boiled water alerts issued in 2012 and 2013 which affected 40,000 and 1.3 million citizens, respectively [23, 33–36]. Tap water is a product that is consumed regularly and supplied without advertisement; thus consumers rarely consider the potential of associated risk factors.

5 Evaluation of Individual and Population Prevention Approaches

Although prevention of specific risks at the individual level would appear to be the optimal method to prevent developing an affliction, such methods have in fact proven extremely difficult to effectively implement. Confounding factors of individual prevention include difficulty reliably identifying relevant individuals and risk factors, individual resistance to the high-risk label, and general noncompliance of individuals with specialized risk-reducing regimens. Population-level prevention strategies circumnavigate many of these issues, providing greater efficiency in prevention by applying general measures to lower the overall risk of an affliction to an entire population, undifferentiated by its previously-established risk status [37].

5.1 Prevention on an Individual Level and the Prevention Paradox

One of the primary examples which can be used to show the difference between individual and population risk levels is the 'prevention paradox' [38]. For any given affliction, individuals categorized as 'high risk' make up a small minority of the affected population, greatly outnumbered by individuals whose risk is predicted to be average or low because, compared to the overall population, the number of high-risk individuals is generally low. As such, although the probability that individuals qualifying as high-risk will suffer from their categorized affliction is high, the probability that a given individual will develop said affliction in the high-risk category is still relatively low [38].

Difficulties of Individual Intervention. Individual risk is often difficult to determine, as risk factors for most of society's common ailments are numerous, complexly correlated, and difficult to determine as causative. This last point contributes to the difficulty of influencing individual compliance: inciting behavioral change drastic enough to perceptibly alter individual risk levels is a complex and unscientific procedure involving individual appeal, personal devotion of time, effort, and conscious thought. This is even more difficult to achieve when no definitive causality between future risk and current behavior can be proven. Even when individual intervention succeeds in altering a single person's contribution to elevated risk factors, this has no perceptible impact on the overall population prevalence of an affliction given the number of individuals which typically make up a population in such investigations [39].

5.2 Prevention at a Population Level

Prevention at a population level refers to the measures, which are taken by a population, rather than at an individual basis to reduce the prevalence of a risk. This implies that preventative measures are applied across a population, rather than evaluated as individual risk factors. As such, the aim of population-level prevention approaches is focused on reducing the probability of a given risk, both for individuals who have been identified to display elevated risk factors, and those whose risk levels are within normal or even low ranges [39].

Methodology, Implementation and Efficacy. Population level prevention may include interventions at both community and national levels. Community prevention includes local regulations, such as legislative restrictions or price increases associated with products or activities. National level prevention is used to describe mass distribution of health and safety information, which governments or private groups use to convey messages to the public, with the goal of encouraging behavioral change. National level risk intervention has been shown to be measurably more effective than community level risk prevention approaches, which in turn is more effective than individual prevention measures [39].

5.3 Case Study: Vaccinations

Of all the controversies, which have surrounded medical treatments and scientific advancement, vaccinations are perhaps the most factually supported by both scientific and medical communities. Recently, populations have become progressively more susceptible to massive disease outbreaks as they become more urbanized and interconnected. Global interconnection among urban centers begs the question – how have massive outbreaks of deadly pathogens been circumvented in the past decades?

The last decades have experienced notable scares –Ebola, avian flu, H1N1 virus, and MRSA all worth mention – but thus far, there have been no modern pathogens, which scourge the population in the manner that the "Black Plague" affected Europe. While advancements in medical treatments undoubtedly play a role in this, medical, scientific and statistical evidence all strongly indicate one inevitable truth: population-wide vaccinations have advanced the human condition in relation to pathogenic, communicable diseases. Data show significant decreases in infections of previously devastating, debilitating diseases including smallpox, polio, measles, mumps, rubella, tetanus, diphtheria, varicella, and multiple strains of hepatitis [40].

While individual treatments for these conditions are available with more or less success depending on the individual case, population-wide prevention measures have significantly reduced the spread and propagation of these pathogens on a scale previously unimaginable and practically impossible while using only individual-level reactionary treatments [40]. However, with the current anti-vaccination movement in the United States and other parts of the world, some diseases that had previously been eradicated are reemerging, such as the Disneyland measles outbreak in 2015 [41]. In India, suspicion of the West also has sparked aversion to vaccinations [42].

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Development of a Risk Assessment Tool for Small Scale Gold Mining in the Philippines

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Abstract. Gold mining is a major economic activity in the Philippines participated in by large-scale, artisanal and small-scale entities. Small-scale gold mining has been a source of opportunities for jobs and livelihood to thousands of people. However, this sector is described as an informal and unregulated industry with minimal standards. This situation has raised concerns on risks that may affect its sustainability. Locally, a working organization is required to undergo self-assessment and inspection. In the absence of a risk assessment tool, this paper presents the development of this tool for a systematic examination and identification of the hazards on small-scale gold mining in the Philippines. To assess its usability, officials of the Provincial Environmental Natural Resources Office and the miners/operators used the tool at sites engaged in surface, underground or compressor mining. The results showed low compliance to standards and violations for the gold small-scale mining activities is due to the lack of information regarding the standards. It also showed that the top hazards identified in specific site depends on the choice of mining and extraction processes. Based on user evaluation, the risk assessment tool is effective, easy to learn and covers most hazards in small-scale mining in the Philippines.

Keywords: Risk assessment · Small scale gold mining

1 Introduction

Small-scale gold mining in the Philippines contributes to employment and the Philippines' Gross Domestic Product (GDP). Employment is one of the most obvious result of gold mining. According to Kippenberg, the number of people working in small-scale gold mining is estimated at 200,000 to 300,000 in 2014 [1]. Other contributions of small-scale gold mining are the Gross Domestic Product input of the Philippines. From 1998 until 2002, there was a decline in large-scale mineral production, both metallic and non-metallic. According to AGHAM, the small-scale sector has been the "saving grace" of the mining industry [2]. It has registered an average percent contribution of 28.7% in the total gross production value, and the production made by informal small-scale miners, whose extracted ores were sold to the black market and unaccounted by the Central Bank, are not even included [3].

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There is an apparent high accident rate in small scale gold mining. Due to under-reporting, there are insufficient data on the number of deaths and accidents that occurred in small-scale mines in the Philippines. The majority of the small-scale gold miners in the Philippines are unregulated and the risks of accidents are high [4]. A compilation of mining accident reports created by GMA News showed that 87.5% of these mining accidents are in small-scale gold mining [5].

The Philippines' Department of Labor and Employment Order No. 57-04 [6], stipulates the guidelines on effective implementation of labor standards enforcement. In Sect. 1, the Labor Standards Enforcement Framework shall ensure compliance with labor standards by self assessment and inspection. Therefore, the distribution of checklist on compliance with labor standards for self-assessment had to be conducted. In line with DOLE 57-04, a risk assessment tool is necessary for these organizations to evaluate their performance, to avoid further accidents in the future and to ensure safety of the miners. This will also be helpful for the implementation of inspection and self-assessment of the Philippine government.

A risk assessment tool is required to have a detailed and systematic examination to identify and evaluate the work environmental hazards in the gold small-scale mining and operations. This tool is useful to prioritize the risks and evaluate their current controls. In this way, miners, tunnel owners, operators, and the local government units (LGU) will be able to implement safety improvements.

2 Methodology

2.1 Model Development

There are six main hazards and are required to be observed and evaluated in any working environment according to OSHA of United States Department of Labor [7]. These are safety hazards, chemical and dust hazards, physical hazards, biological hazards, ergonomic hazards, and work organization hazards. These hazards were then matched to the hazards observed in different small scale gold mining sites.

At the sites observed, the processes in extracting ores, capturing gold, and refining gold were determined. Hazards in each process were then recorded. Table 1 shows the different processes used in the six sites observed. The processes observed in the sites have some similarities and combination of processes, hence similar hazards.

A preliminary set of risk assessment template was created and matched to the standards required for small-scale mining from DENR Administrative Order for Small-Scale Mining No. 97-30 [8] and Philippine Occupational Health and Safety [9]. Figure 1 illustrates the framework of the developed risk assessment tool. Hazards were grouped according to the nature of the hazards.

2.2 Model Application

In order to validate the risk assessment tool, PENRO (Provincial/Municipal Environment and Natural Resources Officers) and miners were invited to use the tool. Three main sites were visited: Site X with compressor mining, Site Y with surface mining,

Table 1. List of observed sites and their corresponding processes

Sites	Processes		
Site A	Underground ore extraction	Milling ores and panning	Use borax and nitric acid to refine gold
Site B	Underground ore extraction	Milling ores, uses cyanide	Use borax to refine gold
Site C	Underground ore extraction	Milling ores, panning, use of lead and zinc nitrate	Use borax to refine gold
Site D	Compressor/ Underground ore extraction	Uses mercury to capture	Use nitric acid to refine gold
Site E	Underground ore extraction	Use mercury, cyanide, and calamansi	Use borax and nitric acid to refine gold
Site F	Underground extraction	Uses cyanide to process ores	Use nitric acid

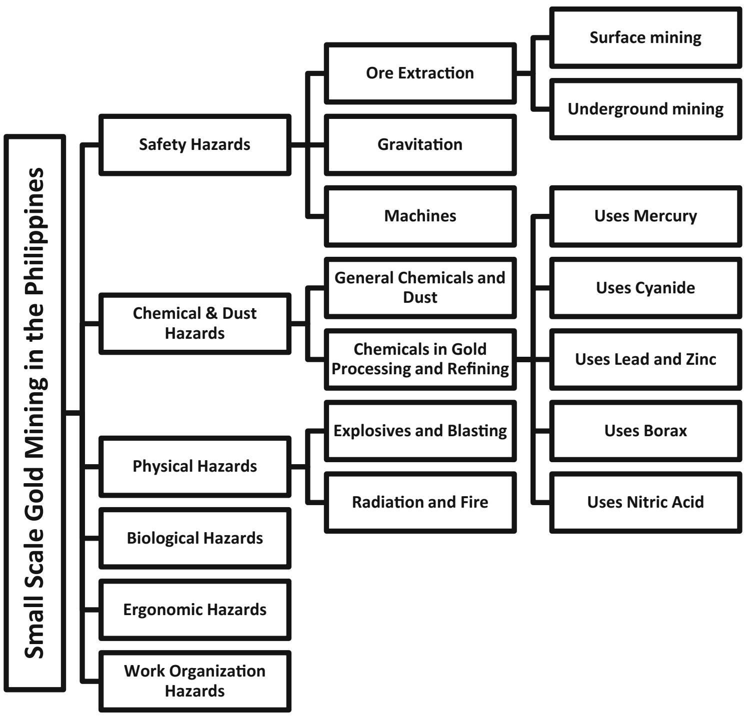

Fig. 1. Framework of the developed risk assessment tool

and Site Z with underground mining. After the participants used the tool. Questionnaires were answered and the tool was rated according to its usability. Cohen's Kappa was used to check the agreement of assessors to show the existence of individual biases on the level of risk [10].

3 Results and Discussion

3.1 Compliance to Safety Standards and Control

The results of the validation shown in Table 2 indicated the percentage of compliance to safety standards used in the risk assessment, percentage of non-compliance to safety standards, and percentage of standards that are not applicable to the process used in the validation Site X and Site Y.

Table 2. Results of the validation of the risk assessment on compliance to safety standards.

Site	Compliance	Non complied	Not applicable
Site X	17%	30%	53%
Site Y	32%	46%	22%

Using the risk assessment tool, in Site X, the PENRO noted that 30% do not comply to the given standards in the tool. Only 17% complied and the rest are not applicable to answer. One of the reason for this result is that compressor mining is prohibited by law. Therefore, only few DAO safety standards are applicable and the rest are not covered by DAO97-30.

In Site Y have 32% complied in terms of compliance to safety regulations of small-scale mining in the Philippines. They also failed 46% in terms of following other standards and regulations from Occupational Health and Safety and International Labor Organization's Safety in small scale mining. One of the reasons why they commit violations is that they do not know the standards. As noted during the interview that they never heard of DAO97-30 and they have not used any risk assessment tool before.

3.2 Strength of Agreement of the Risk Level

To validate the strength of agreement of risk, Cohen's Kappa was used. Table 3 shows their agreement to High Risk, Medium, Low Risk level of hazards in the site.

Table 3. Results of the validation on the strength of agreement among assessors using Cohen's Kappa for Sites X, Y and Z.

Site	Miner & Miner	PENRO & PENRO	PENRO & Miner
Site X	Almost perfect	Substantial agreement	Poor agreement
Site Y	NA	Substantial agreement	Slight agreement
Site Z	NA	NA	Slight agreement

In Site X, the miners both agreed with k = 0.88 which means, almost perfect. The PENRO and miner show a very poor agreement of k = −0.039, which means that they do not agree at all. In Site Y, the two PENROs agreed well with k = 0.889, but the PENROs and miners have fair agreement that ranges from k equal to 0.23 to 0.26. In Site Z, the results show k = 0.098 which shows weak agreement on the degree of risk. This implies that the PENRO feels that hazards have different degrees compared to the miners. Therefore, there are gaps between the knowledge and experiences of the miners and PENROs. In the interview conducted, they noted their differences in safety knowledge and exposure in mining.

3.3 Usability Test

A usability questionnaire was used after using the risk assessment tool. It is measured in three parts: effectiveness, learnability, and satisfaction of the tool. Table 4 shows the average rating given by the assessors ranging between 4.4 (highest) and 3.4 (lowest).

A high rating was given on the representation of current hazards in the risk assessment tool. Assessors agree that the tool has a satisfying content. They gave a rating of 4–5 on effectivity and learnability. In general, when using the risk assessment tool, assessors might have different perceptions but all of them have acknowledged the immediate need for the tool, and have given a high rating on its usability namely in its content and learnability.

Table 4. Average of PENROs usability test scores. 1 as non satisfactory and 5 as highly satisfactory

Usability	Ave. rating
Effectiveness	
The instruction is easy to understand	3.4
The standards/controls included in the tool are clear	3.8
Fast completion of the each table	3.8
No errors	4.3
Learnability	
The risk assessment tables are consistent	4.4
Readily available instructions	3.8
The steps are easy to remember	3.8
Appealing and pleasant to the sight	4.4
Satisfying/attitude	
Each part of GSSM-Risk Assessment Tool addresses all the hazards in the site observed	4.0
In general, the GGSM-Risk Assessment Tool represent the hazards of GSSM in the Philippines (Satisfying Content)	4.2
Easy to use	3.6
Satisfying learning outcome	4.4
Total	4.0

4 Conclusion

The risk assessment tool was developed, tested and improved during the course of this study. Using the tool, the assessment results show that the PENRO representatives have identified the percentage compliance of gold small-scale mining to be low. Follow up interviews showed that low compliance and violations of the miners are due to the lack of information regarding the standards set by government. It also showed that the top hazards identified in specific site depends on the process of mining of ores (e.g. surface mining) and ways of extracting gold (e.g. use of mercury).

Furthermore, analysis from Cohen's kappa of the responses showed gaps between the PENRO and the miners in terms of risk evaluation. Lastly, based on user evaluation, the risk assessment tool is effective, easy to learn and covers most hazards in small-scale mining in the Philippines. Hence, the tool is useful as a self-assessment and inspection tool for small-scale gold mining.

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Proposal of a Mathematical Model of Prediction of Sinistrality Values for Valuation of Organizational Management Indicators, Applied to the Construction Industry

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Abstract. The construction sector has a set of very specific and unique characteristics that demarcate it from all other sectors. This is associated with a strong precariousness and labor turnover, plus the widespread practice of subcontracting. The pertinence of the study carried out is framed in the necessity of evaluating and valuing the management indicators, through accident rates that are statistically valid. In order to obtain the indices as a function of sectoral and market management variables, several statistical models were developed with the capacity to predict the behavior of these indices. Exogenous variables, such as the unemployment rate and the GDP growth rate of Portugal, were included for this purpose. These statistical models function as predictive models, provided that the coefficients of the independent variables are significant. Linear regressions were used because, due to the temporal shortage of data, the other types of regression would hardly prove to be robust. Also, were tested dozens of models, and the overwhelming majority did not show any statistical significance. Nevertheless, we obtained 3 (three) partially significant multiple linear regression models. Thus, as a final result of this work, it was verified that only (2) two models, demonstrated to have good predictability and reliability for future use. Being that these appear as relevant variables, the unemployment rate and the training costs per worker. These models can be used by companies in the industry, such as tools for the prevention of accidents at work.

Keywords: Safety · Models · Construction · Prevention

1 Introduction

The construction sector has a whole set of very specific and unique features that demarcate all other sectors. This is associated with a strong precariousness and labor turnover, plus the widespread practice of sub-contracting [4].

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Perhaps we can not talk about work accidents without addressing the issue of working conditions in which it is carried out in space and surrounding environment. As well as the adequacy of the conditions of professional performance in the particularities of each task developed. Everything always translates into risks for the workers.

According to the International Labor Organization (ILO), where there is work, there is a risk. Given that the number of work accidents is evidenced in the widely-known statistics [6].

According to Kartman's study, construction work accidents are at the root of many human tragedies. Discouraging workers, inter-break the building process, affect adversely the costs, productivity and reputation of this industry, as well as delaying the progress of society [3].

When the accident statistics are analyzed, there are sectors of activity, where the probability of occurrence of the accident at work, as well as the severity of its consequence is higher. As is the case of the construction sector, where it is imperative to take up measures and actions aimed at reducing and/or minimize these statistics sustainably. These black numbers mean a catastrophe in social and economic terms for the whole community, without exception [5].

Faced with this problem and considering safety in the construction a vital mission and of primordial meaning for the society in general, it was intended with the present study to develop a mathematical model. That has the ability to explain the behavior of a given variable due to several sectoral and market variables. It is intended that this will serve as a support tool in making decisional actions of top management of companies in this sector. Since to predict what its loss ratio, allows the possibility of a timely and effective planning of investments in prevention and OHS in office and the workplace. The relevance of the study conducted relates to the need to assess and enhance the management indicators, through loss ratios that may be statistically valid. To obtain the rates due to sectoral management and market variables were developed various statistical models with behavior prediction capacity of these same indices. To this end, it included exogenous variables, such as the unemployment rate and the growth rate of GDP of Portugal. With the introduction of the variable unemployment rate, it allowed the creation of models that depended on an exogenous and economic variable.

These statistical models act as predictive models and can be used by companies in the sector as potential tools for the prevention of occupational accidents.

2 Materials and Methods

In this sense, the construction of a first version of the accident rates, resulted from a selection of common variables in different organizations. That come from a cross-sectional survey among members of a business association (BA) of the Construction and Public Works sector, complemented by others from a state entity.

These socio-economic and financial variables were collected through an official questionnaire that was applied to the various business organizations of different dimensions (staff and annual turnover), which constitute this association.

In the development of this work were applied different methodological approaches that are based on three components of fundamental bibliographic research:

Scientific Component: Consultation and analysis of several articles and scientific papers with peer review, as basis for framing and orientation of the theme and proposed objectives.

Legal Component: Support in diverse legal and normative diplomas, as much at the historical level as at the present time. In order to sustain the development of this work in the guidelines issued by the bodies that oversee and supervise the rights and working conditions, both nationally and internationally.

Technical Component: Research and study of several statistical models, of treatment and data analysis.

Which are also supported in five phases improvement continuous, as shown in Fig. 1.

Fig. 1. Phases of the applied methodology, based on continuous improvement cycle [6].

Phase I: Planning and definition of the variables and statistical indicators, leading to the completion of the study - Definition of key stakeholders, what are their objectives and what kind of influence will they have on the final results. Establishing the objective of the evaluation and the results to be achieved; Planning of the necessary activities and definition of the time period for carrying out the research.

Phase II: Collection and sorting of data from the questionnaire, to characterize the sample and consequent exploratory study - The deficit of records related to work accidents was one of the greatest difficulties in the accomplishment of this study, having as consequence the necessity of its evaluation of form Indirect. Choice of variables in order to achieve the purpose of evaluation. For this are selected those for which data are available, easy to obtain and have the desired accuracy.

Phase III: Treatment and analysis of statistical data - Use of data already available, originating from statistical collection systems for official treatment. It is also used to extrapolate data so that the final result is as faithful as possible to the situation under study. The aim is to determine what is related to work accidents and what their degree of intervention is, in order to quantify their effects through analysis techniques.

Phase IV: Development of mathematical models, based on variables with statistical reliability - In this phase the values obtained are related to variables related to work accidents.

Phase V: Testing and validation of mathematical models with application to practical cases - Regarding the results, proceed with due consideration to interpretation. Whenever possible, it addresses references and assumptions, objectives, and limitations of data credibility. Due to this it will be necessary to use qualitative and explanatory sensitivity analyzes. To draw conclusions and evaluate the effects of interpretations of the results obtained. Depending on the results obtained, it evaluates the need to apply a new cycle of continuous improvement of the socio-economic assessment of accidents at work, taking into consideration that the new variables selected are representative of reality in the study.

2.1 Questionnaire

The information was collected through the questionnaire and treated for statistical purposes in the present research work. The questionnaire is divided into six sections that cover: (0) General Business Organization Information, (1) Employability Conditions, (2) Personnel Costs, (3) Occupational Health and Safety, (4) Professional Training and (5) Complementary Social Protection.

2.2 General Sample Characterization

The questionnaire was applied to a representative sample of 58 companies in the Construction and Public Works sector belonging to a business association (BA). Group A: more than 1000 workers, Group B: between 501 and 1000 workers, Group C: between 101 and 500 workers and D: less than 100 Workers) for the study period.

At the geographical level this covers the territory of mainland Portugal, and corresponds to an annual average of 21,190 workers (approximately 10% of sectorial employability at national level). The reference period was defined between the years 2002 and 2007. Or in aggregate terms (between the Sinistrality and Training indices) is a sample with 6 elements (in temporal terms). It can, in some cases, be broader and/or shorter, given the data provided by the entities.

The sectoral level is on the activities of the section and subsection F of the NACE Revision 3, including the sector of Construction and Public Works.

2.3 Methodology of Processing and Analysis of Data

The raw and sectoral data collected were provided by a business association (BA), complemented by others provided by a state entity. They are relating to two different periods (1997–2007 and 2002–2007) with a common range. These include: investment in training; Assiduity; The number of workers; Number of training courses per employee; Participation rates in training actions; Costs of training actions per worker and participation; Percentage of workers covered by training in relation to the total, medical examinations per 100 workers, hours of training, accident rates and others.

The data obtained through the questionnaire, were treated with the software SPSS 17.0. In all tests performed, the 95% confidence level was used. And a test value greater than 0.05 ($p > 0.05$) which, if the value was lower than the hypothesis, was rejected.

Considering that small samples (less than 30 elements) were present, the Shapiro-Wilk test was applied to verify the normality of the data and verify if the behavior of each variable followed the Normal law. If so, the t (Student) test was used. This test was used to verify if two variables (for example, two of the accident rates) presented equal or different behaviors at the level of the mean value. If the test is significant then there is a high probability that your means are different.

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3 Results and Discussion

As can be seen from the overall objective of the study, this study aims not only to show that there are relations between certain variables, but also to try to quantify them. However, as a result of the treatment, only those referring to the Training showed statistical reliability. Due to this situation and to continue its study, exogenous variables were included, such as the unemployment rate and the growth rate of the Gross Domestic Product (GDP). To try to explain the behavior of the accident rates.

These statistical models function as predictive models as long as the coefficients of independent variables are significant. To determine the results, the following steps were followed:

Step 1: Linear regressions were used due to the temporal shortage of the data (samples at 6 years), since the other types of regression would hardly prove to be solid.

Step 2: The choice of variables followed a process of trial and error. Thus we started with endogenous variables, including and removing several variables. But after the impossibility of obtaining multiple linear regression models with them, the GDP growth rate and the unemployment rate were chosen as exogenous variables.

Step 3: These choices were related to the notion that Construction is above all an economic activity with a significant weight in Portuguese GDP. Thus, the behavior of GDP could be expected to influence the activity of the sector, as well as the unemployment rate. These will serve as a complementary indicator of economic progress. Thus, dozens of models were tested until five (5) were statistically valid.

Step 4: Finally the validation of the non-rejected models was carried out. In this way, 3 (three) partially significant multiple linear regression models (no. 1, 3 and 4) were obtained, 1 (one) statistically significant simple linear regression model and 1 (one) model No. 5) of statistically significant multiple linear regression.

Of the five (5) models obtained, paragraphs 1 and 4 were rejected because there was at least one statistically insignificant coefficient. Therefore, the three (3) models that demonstrated statistical reliability were presented below:

Model No. 2 - Sectoral Incidence Index - Variable: Unemployment Rate (X_1):

$$IIncidência(AE) = 14{,}891 - 0{,}990X_1 \tag{1}$$

Model No. 3 - Sectoral Severity Index - Variables: Unemployment Rate (X_1), Participation Rate in Training Shares (X_2) and Training Hours (X_3):

$$IGravidade(AE) = -1,129X_1 + 0,997X_2 + 0,548X_3 \tag{2}$$

Model No. 5 - Sectoral Severity Index -Variables: Unemployment Rate (X_1), Training Costs per Worker (X_2):

$$IGravidade(AE) = 2,281 - 0,431X_1 + 0,010X_2 \tag{3}$$

Later, the validation of the models was verified by verifying the extent to which the values observed in the companies of the accident rates (where the models were statistically significant) would deviate or approximate the values predicted by the models. The following is the graphical analysis of the validation of the models that were statistically valid:

As can be seen from Fig. 2, the error (difference between the predicted value and the observed value) is never very high. The predicted value is practically coincident with the value observed in 4 of the 6 years, reason why it is considered to be a model with good predictability and of great future reliability.

When analyzing the graph of Fig. 3, it is verified that in most of the predicted values of the Severity Index are almost always negative, which is absurd, reason why the model should be rejected.

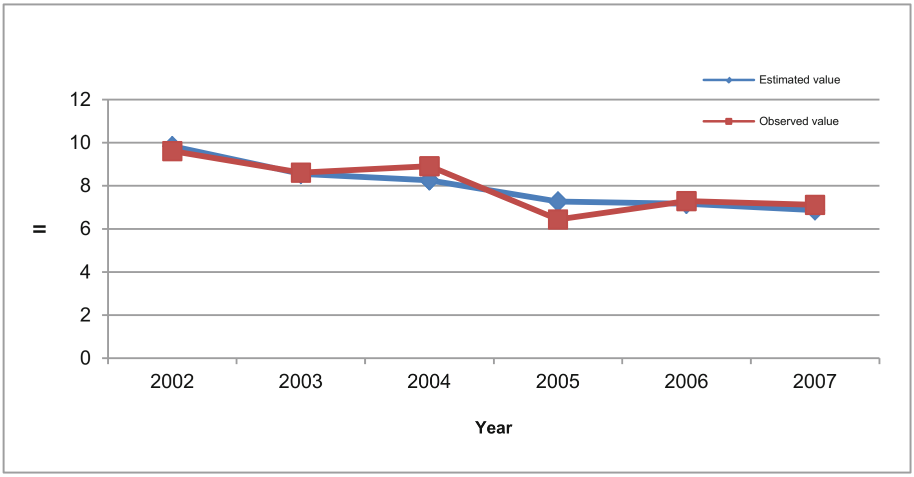

Fig. 2. Comparison of the observed and estimated values of the AE Incidence Index (Model No. 2)

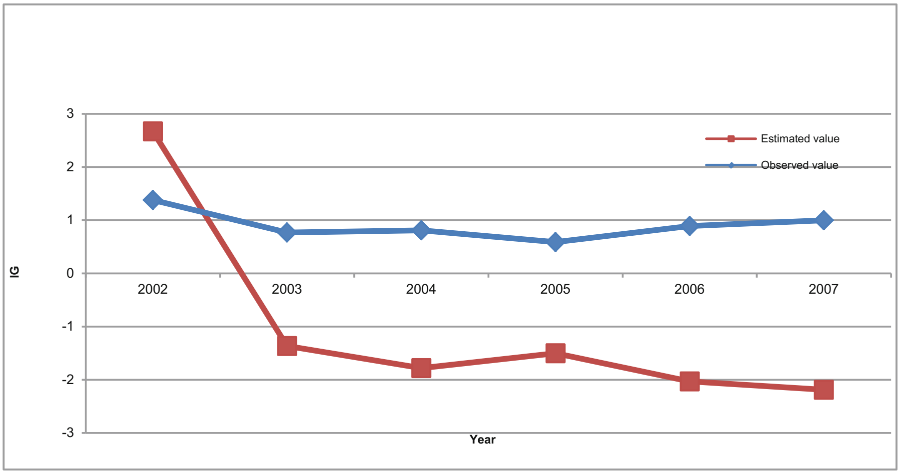

Fig. 3. Comparison of the observed and estimated values of the AE Severity Index (Model n° 3)

Regarding the model no. 5, this one presents values of the Gravity Index also very close to those observed. This means that in the period between 2002 and 2007 the severity index does not deviate from the values predicted by this model. In that the explanatory variables are the unemployment rate of Portugal verified in that year and the training costs per worker. From the analysis made to the graph of Fig. 4, it can be seen that the values are practically coincident in every year. If there is only one (very slight) departure in 2006 (where the observed value is very slightly higher than expected), it is considered to be a very reliable model for future use.

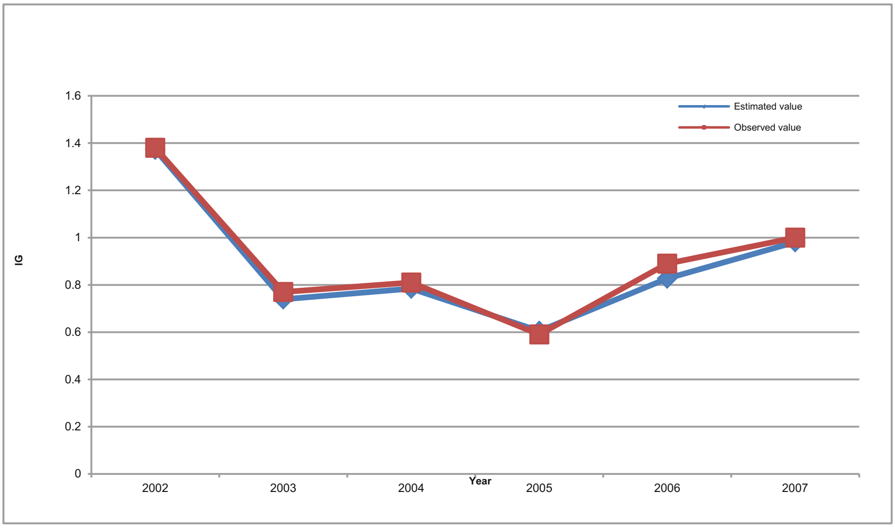

Fig. 4. Comparison of the observed and estimated values of the AE Severity Index (Model n° 5)

As a final verification of the validation of the models, rejection of the model no. 3 was obtained, as there was a significant difference between the estimated and observed values.

4 Conclusion

From the results presented in this work, it can be seen that only models no. 2 and 5 have shown great reliability for future use. Given that the actual figures are practically coincident with those foreseen for each year. In these, the unemployment rate and training costs per worker appear as relevant variables.

Regarding this last variable, already in 2009, Costa, questioned the effectiveness of training for a very significant number of companies surveyed for their study. It was verified that the statistical models used had an apparently neutral or even negative effect of the OHS training regarding the accident rate [1].

That is to say, a greater investment in training corresponded to an increase in the number of accidents at work. Although statistically valid, it was concluded that these results could not be related to the training itself, but to its quality. Even so, since they have no effect on workers, they do not promote Prevention and Security, making the investments made completely irrecoverable. On the contrary, the investment in occupational health and safety technicians would have a positive return [2].

With regard to the conclusions drawn in the present study with a completely different sample and in another industrial sector, the conclusion is the same in investments made in training. In other words, it was verified through model 5 that, statistically, the participation rate in training actions has a direct effect on the severity index of work-related accidents among BA associates. It was concluded that an increase in the participation rate in training actions would lead to an increase in the incidence rate. It is understood that the more workers involved in training and/or more hours of training, the more work-related accidents would occur. Meanwhile, the unemployment rate would have an inverse effect on this index, that is, an increase in the unemployment rate causes the index to decrease. This second reading is supported by model no. 2, which shows that the increase in the unemployment rate has a beneficial effect on the incidence index. That is, an increase in the unemployment rate causes it to decrease. Conclusion also unfavorable.

These results are highly troubling and, once again, strongly question the quality of the training given in companies. As well as the legal model in this area is defined. It proves once again that it is not enough to give training, but that the fundamental one is its adequacy to the reality of each company. With the risk, here proven, of the complete lack of return on investment made under these conditions.

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Behavior Monitoring with Non-wearable Sensors for Precision Nursing

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Abstract. Non-wearable sensors utilizing advanced image-processing and sensing technologies for capturing an individual's behavior in real-world settings are now available. Wearable sensors are difficult to use, especially for long-term recordings, because the batteries for these sensors must be exchanged or recharged. Behavioral data collected using non-wearable sensors can be used for precision nursing, which indicates individualized risk management and intervention plan based on the understanding of individual risk and other health status. In this study, we applied the developed non-wearable technologies to evaluate a person's gait ability, which is an important factor for creating a fall prevention program.

Keywords: Behavior monitoring · Precision nursing · RGB-D sensors · Mini-mental state examination · Barthel index

1 Introduction

Falls can cause serious injuries such as bone fractures in elderly individuals, sometimes rendering them bedridden. Falls are actually the second leading cause of accidental death worldwide, and the highest number of fatalities from falls are among people 65 years of age and older. The decline in physical function associated with aging puts elderly people at a higher risk of falls, and many of them may end up requiring long-term care. In a long-term care facility, care personnel or professional caregivers assist residents with special needs to maintain or even improve their health. However, elderly individuals injured from a fall could suffer substantial declines in their physical as well as cognitive function, which would negatively affect their quality of life.

Technological advances now make it possible to collect and analyze data on people's movements to reveal potential risk factors for falls. Wearable sensor systems have been used to identify fall risks in many research studies, but capturing behaviors in real-world settings using wearable sensors is difficult because the batteries of these sensors must be exchanged or recharged. Consequently, non-wearable sensors utilizing advanced image-processing and sensing technologies are more suitable for capturing an individual's behavior over extended periods. Data collected using these non-wearable sensors will allow us to conduct "precision nursing" which identifies individual health risks

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(e.g., fall risks) and creates individualized intervention programs (e.g., fall prevention program).

In the United States, approximately 37.3 million falls that require medical care occur annually, and 20 to 30% of the injuries are classified as mild to severe. The risk of falls increases as people age, probably due to changes in physical, mental, and sensory functioning [1].

According to the Tokyo Fire Department of Japan, falls account for approximately 270,000 emergency transports among people 65 years of age and older each year in Tokyo [2]. The national total for elderly individuals requiring emergency transport due to falls is likely more than 10 times this amount, as 90% of Japan's population lives outside the Tokyo metropolitan area. Hayashi estimated that medical and long-term care for fall injuries in the elderly population cost as much as 900 billion yen annually [3].

The risk factors for falls vary but can be categorized into three types: (1) personal factors including physical and mental health conditions, (2) external factors including medications such as sleeping pills and psychotherapeutic drugs, and (3) environmental factors such as the types of care equipment used and care provided by caregivers [4].

Some researchers have examined the relationship between falls and personal factors. For instance, in our previous study, we found that people with symptoms of dementia have a higher risk of falling when excited compared to people without dementia. [5]. Soyano reported that people with visuospatial cognitive dysfunction have a higher risk of falls because their ability to recognize the positional relationship between objects is diminished [6].

As for the relationship between falls and depression, which is a common symptom of dementia, Stalenhoef and colleagues reported that elderly people who are in a depressive state and have fallen twice before have an increased risk of subsequent falls [7]. In terms of physical ability, one study found an association between slow walking speed and falls [8], and another study pointed out that the action of changing direction is the most common cause of falls [9].

Regarding external factors, falls have been shown to be affected by medications that cause dizziness, drowsiness, convulsions, and numbness. These medications include antipsychotic medications, anxiolytics, antidepressants, sleeping pills, and antiepileptic drugs [10]. Moreover, Nevitt et al. reported that approximately two-thirds of people who had experienced falls fell again within a year [11].

Recent research has turned to investigating the use of non-wearable sensors for monitoring behavior. Robinovich et al. installed cameras in two long-term care facilities and collected data on 227 falls from 130 people over nearly three years [12]. Their results showed that the most common cause of falls was incorrect weight shifting, followed by a trip or stumble, hit or bump, loss of support, and finally collapse. They also revealed that forward walking, standing quietly, and sitting down were strongly associated with falls.

The purpose of this study was to develop and operate a behavior monitoring system for recording the natural walking of elderly individuals. We analyzed the data to understand the mechanism of falls by clarifying the relationship between gait and a person's level of cognitive and physical function.

2 Method

We conducted an observational study between October 2016 and March 2017. We collaborated with three nursing facilities in Japan and installed three RGB-D sensors (Microsoft Kinect v2) on the ceilings (height: 5 m) of hallways and common spaces at each facility.

In 2016, we constructed “a smart living lab” with numerous embedded sensors for collecting behavioral data using artificial intelligence-based sensing technologies. Figure 1 shows a map of the smart living lab, and Fig. 2 shows the actual lab. Currently, over 10 RGB-D cameras and 200 ultrasonic location sensors are installed in this lab. Before we installed the sensors in the actual nursing facilities for collecting behavioral data from elderly participants, we confirmed the effectiveness of non-wearable sensing technology in the smart living lab.

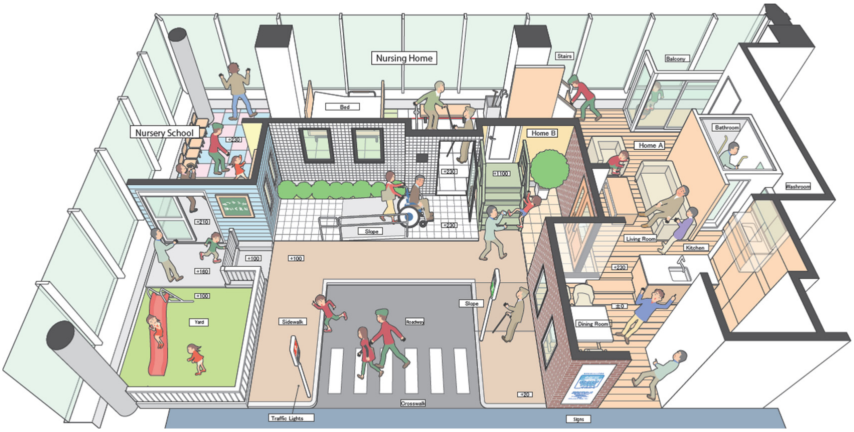

Fig. 1. Map of the smart living lab at the National Institute of Advanced Industrial Science and Technology (AIST) in Japan

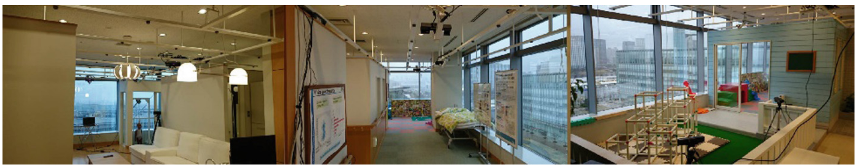

Fig. 2. Photograph of AIST’s smart living lab

We recorded the activity at the nursing facilities 24 h a day. Figure 3 shows the floor plan of one facility that has a maximum capacity of nine residents. The numbered blue stars indicate the locations of the three camera sensors. Example screenshots from videos recorded at the facility are shown in Fig. 4.

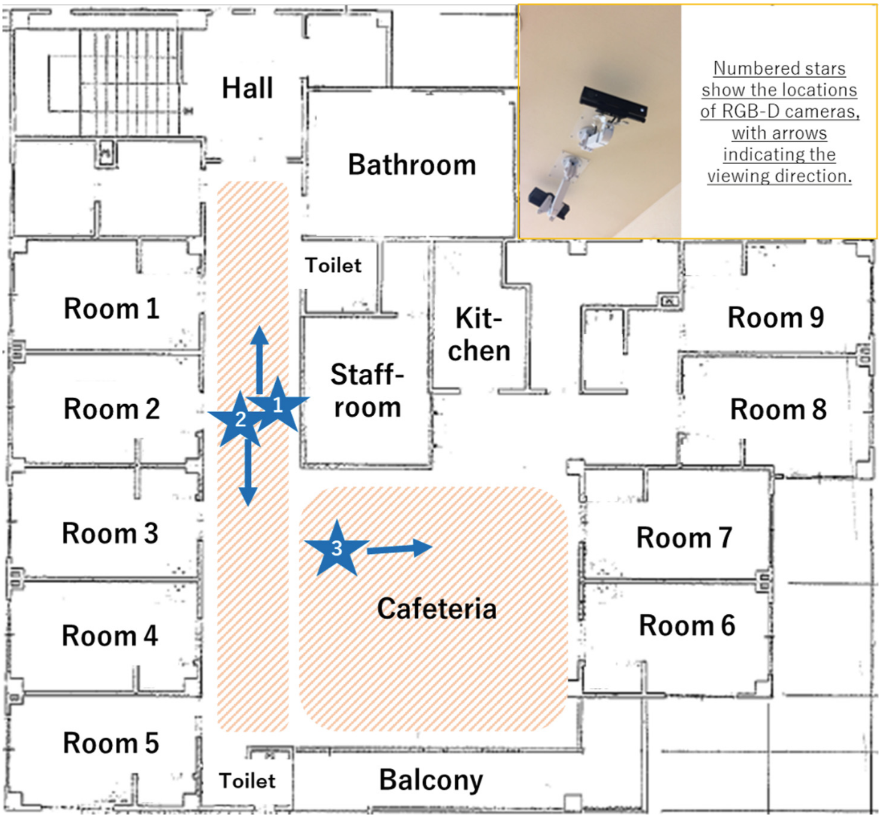

Fig. 3. Floor plan of one collaborating nursing facility

Fig. 4. Screenshots from videos recorded at a nursing facility

Twenty-two elderly people (4 men and 18 women) participated in this study. We used the mini-mental state examination (MMSE) and the Barthel Index (BI) to assess each participant's level of cognitive and physical function, respectively. Specifically, to assess one's cognitive level using MMSE, each participant filled MMSE questionnaire. To assess one's physical level using BI, care personnel assessed his or her physical level based on their observation.

2.1 The Non-wearable Sensing System

Figure 5 shows the configuration of the non-wearable sensing system, which consists of RGB-D cameras, a face recognition engine, a registered person identification engine, and individualized data storage. The key idea lies in the combination of RGB-D cameras and face recognition technology so we can individualize data collection without wearable sensors. The stored data will allow us to conduct precision nursing care and precision risk management, which are new methodologies customized for each individual.

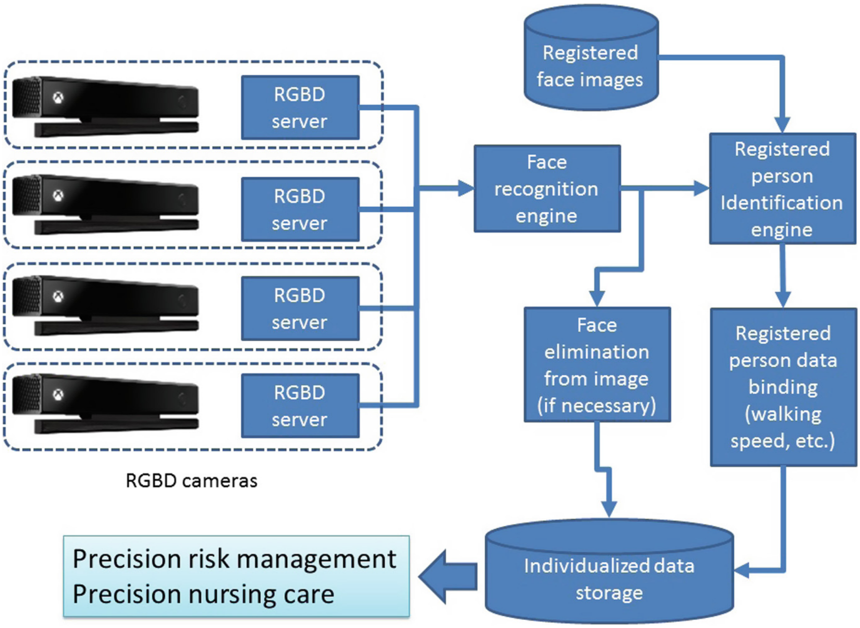

Fig. 5. Configuration of the non-wearable sensing system

3 Results

In residential care facility H, all nine residents agreed to participate in the study. The total monitoring time was approximately 3,548 h. In residential care facility S, seven of the nine residents agreed to participate, and were monitored for approximately 3,504 h. In nursing home C, an adult daycare facility, six elderly people participated in the study. In facility C, we monitored participants for approximately 1,160 h because nursing care was provided only during the daytime (Table 1).

We successfully collected and analyzed the walking speed data and observed the changes in walking speed over time. For example, the average walking speed of an elderly woman in facility H over three days was 0.9 m/s (Fig. 6). Her slowest walking speed was observed between 7 am and 8 am each day: Day 1 = 0.62 m/s, Day 2 = 0.66 m/s, Day 3 = 0.56 m/s (Fig. 7). The slowest walking speeds and corresponding dates and times are outlined in red.

Table 1. Summary of collected data

	Residential care facility H	Residential care facility S	Adult daycare facility C
No. of participants	9	7	6
Sex	M2:F7	M1:F6	M1:F5
Recording duration days	147 (2016/10/3-2017/2/28)	146 (2016/10/4-2017/2/28)	145 (2016/10/5-2017/2/28)
Recording duration hours	3,528	3,504	1,160
No. of BI scores acquired	9	7	6
No. of MMSC scores acquired	9	7	5

BI: Barthel Index, MMSE: mini-mental state examination

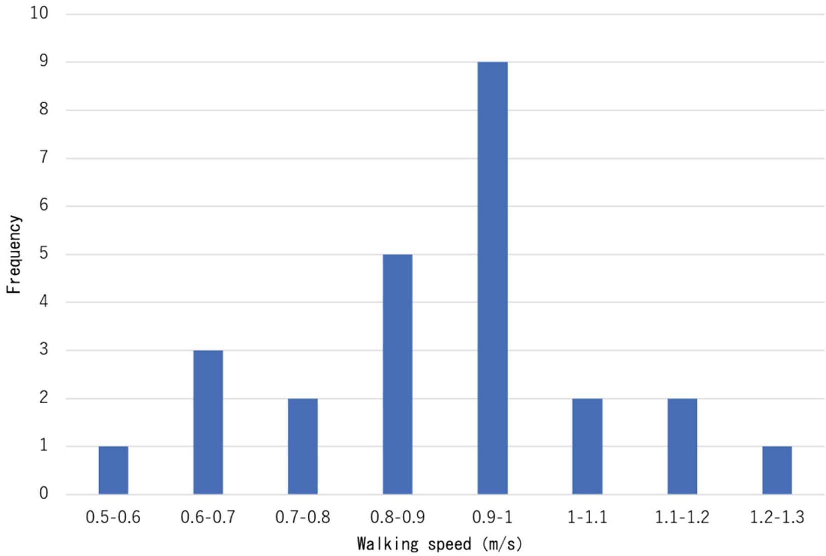

Fig. 6. Frequency of walking speeds over three days

Figure 8 shows the relationship between physical and cognitive function. Each dot represents a participant, and the color of the ID number indicates a specific nursing facility. In the field of elderly care, people whose MMSE score is lower than 21 are suspected to have dementia, and people whose BI score is lower than 60 need assistance with daily activities. As shown within the area enclosed by the red line in Fig. 8, 77.2% of the participants had a BI score higher than 60 and an MMSE score lower than 21.

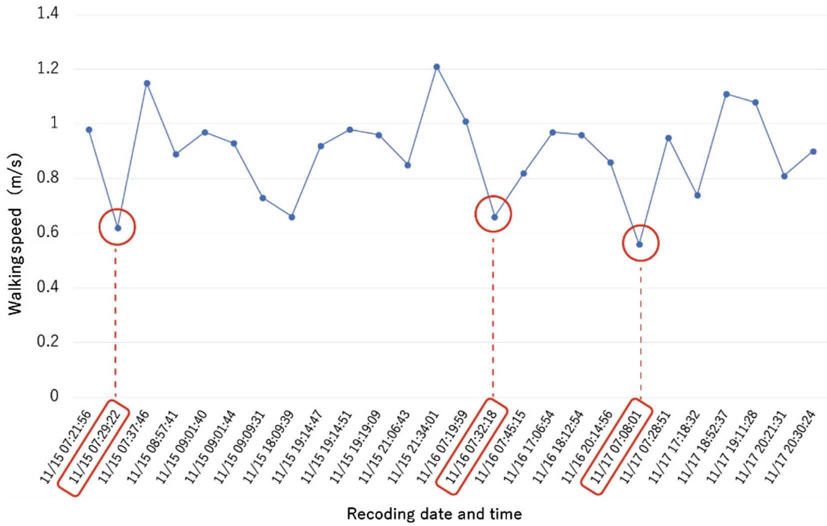

Fig. 7. Circadian variations in walking speed

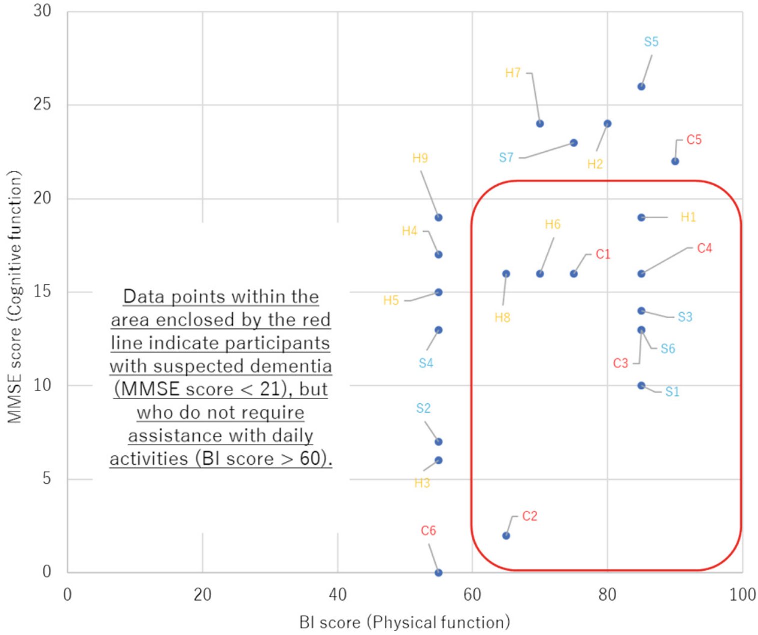

Fig. 8. Relationship between MMSE and BI scores

4 Discussion

We developed and operated a system that recorded the natural walking of elderly people using Kinect sensors. While the timed up and go test has been used to evaluate the gait ability in elderly people, it only measures the time required to walk a certain distance and return to a seated position. Other factors, such as a person's posture and his or her circadian variations in walking speed should be taken into account when evaluating gait.

We found that the walking speed of elderly participants at nursing facilities was not constant but changed throughout the day. Particular behaviors such as walking while looking at something or walking while holding something in one's hand may influence a person's walking speed. Therefore, it will be interesting to analyze walking speed based on different types of behavior.

Analyses of the relationship between MMSE and BI indicated that most participants were physically independent, but levels of cognitive function varied widely. Our hypothesis is that people with low cognitive function but high physical function are at the highest risk for falls. We hope to gather more data to test this hypothesis and to analyze the relationship between falls and the MMSE/BI relationship.

5 Conclusion

We installed Kinect sensors in three nursing facilities and captured real-life walking behaviors of elderly people. We successfully analyzed the walking speed for each individual and observed circadian variations in walking speed. In a future study, we hope to identify gait patterns in elderly individuals and fall risks based on these patterns. Moreover, we hope to reveal the relationship between a person's cognitive and physical function based on MMSE and BI scores and walking speed and to develop a precision nursing program using non-wearable sensor data.

Acknowledgments. This paper is based on results obtained from a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

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Thermal Environment: Case Study of a Meat Processing Industry

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Abstract. The study of the occupational thermal environment must take into account the need to obtain acceptable conditions in terms of health and comfort. The aim of the present study was to evaluate thermal comfort in a meat processing industry. Measurements of temperature, relative humidity and air velocity were carried out for all workstations. Measurements (N = 21) were performed during 5 min, for each thermal amplitude, with the presence of the worker after analyses of workers clothing. After the measurements, "Predicted Mean Vote" and "Predicted Percentage of Dissatisfied" were calculated, for a subsequent proposal of prevention and protection measures. The results demonstrate the need to implement preventive measures to mitigate possible health effects for workers exposed to various thermal environments (design, organizational, material/structural, personal protection and medical surveillance). In conclusion an inadequate thermal environment can rise to psychological discomfort, absenteeism, reduced productivity, increased frequency of accidents and physiological effects.

Keywords: Thermal environment · Thermal comfort · Meat industry

1 Introduction

The study of the thermal environment in the workplace should meet the need to obtain acceptable conditions in terms of health and comfort and be suitable for the human organism, depending on the production process [1].

Human requirements of thermal comfort are related to the functioning of the organism, whose mechanism can be compared to a thermal machine that produces heat according to its activity. Man needs to release enough heat so that its internal temperature stays about 37 °C [2]. This phenomenon is called homeothermia (maintenance of internal body temperature), which ensures optimal functioning of the main functions of the body and in particular of the central nervous system. Homeothermia is ensured when the heat flow, produced by the body, is equal to the heat flow delivered to the environment [2, 3].

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In certain thermal environments, the equality of the heat flows can take place in a pleasant and non-burdensome way for man - it is the so-called neutral or comfortable environment. Outside of this neutral environment, the body may continue to maintain homeothermia, but at the price of certain physiological or behavioral reactions intended to adjust the thermal equilibrium [3].

A neutral or comfortable environment is an environment that allows metabolic heat production to equilibrate with heat exchanges (losses and/or gains) from the air around the worker. In this situation (when heat exchanges between the human body and the environment occur without greater effort), workers sense thermal comfort and his work capacity is maximum [2].

Outside of this equilibrium situation, that is, if the environmental sensations cause more or less heat than is necessary for the homogeny (which happens to be achieved with additional effort that represents overload) causing a decrease in performance at work [2]. In these situations of thermal stress, induced by heat or cold, can constitute a risk to the health of workers, since even taking into account the thermoregulation mechanisms of the organism, they cannot keep the internal temperature constant and adequate [4].

1.1 Types of Thermal Environments

Neutral Thermal Environment. A neutral thermal environment is an environment in which metabolic heat production is balanced by the waste of sensible heat (con-vection, radiation, conduction), respiratory heat loss, and insensitive perspiration, without the individual having a need to fight against heat or cold.

A comfortable environment is a neutral environment for which the physiological parameters that determine the sensation of heat have an optimum value. These physiological parameters are the skin temperature average and the rate of sweating.

The physiological conditions of stable thermal comfort are thermal equilibrium: neither storage nor heat loss; absence of chills; optimal sweating rate; optimal mean skin temperature (function of the metabolic level); relatively dry skin (skin whitening less than 60%); absence of dryness of buccopharyngeal mucosae (partial water vapor pressure of more than 1.5 kPa) [3].

Hot Thermal Environment. The hot thermal environments are environments for which the heat balance, calculated on the basis of the heat exchanges by radiation and convection, is positive. The body must, therefore, activate the different means of fighting against heat.

Several reasons can lead to a situation of thermal stress: increased metabolism; increased air temperature; increase in radiant temperature average; modification of the air velocity when its temperature is higher than the skin temperature average; increased air humidity.

To try to rebalance the thermal balance, the organism reacts fundamentally through three processes called physiological overloads:

– Thermostatic overload: the skin temperature increases, the internal temperature more slowly; the increase of the cutaneous temperature allows to optimize the heat exchanges by convection and by radiation between the skin and the environment.
– Circulatory overload: the difference between the internal temperature and the skin temperature decreases, which means an increase in the physiological conductance, that, in turn, is ensured by an increase in cutaneous blood flow.
– Sweating overload: the optimization of convection and radiation heat exchanges obtained by an increase in skin temperature is not enough to ensure a thermal equilibrium. The body then possesses sweating, which, through the skin's wetting, allows to maintain a certain evaporating flow [3].

Cold Thermal Environment. The cold environments are the thermal environments for which the thermal balance, calculated on the basis of the convective and radiant changes, is negative. The body must therefore activate the different means against the cold. With the exception of air humidity, the set of environmental parameters may be at the origin of such an imbalance. To try to maintain a near-zero thermal balance, different reactions of the organism can be observed:

– Thermostatic overload: low skin temperature in order to reduce the difference between skin temperature and ambient temperature, contributing to the reduction of convective and radiant losses.
– Circulatory overload: as the difference between the rectal temperature and the cutaneous temperature increases, due to lowering of the skin temperature, it is advisable to reduce the physiological conductance of the body. Such a reduction is achieved by reduction of cutaneous blood flow.
– Metabolic overload: if these two adjustments are not enough, the body is forced to increase metabolism in order to compensate for excessive heat losses. This increase in metabolism occurs, exclusively in the skeletal muscles: first occurs an increase of muscle tone; secondly the appearance of chills. Metabolism can be multiplied by 5 in the fight against cold [3].

1.2 Types of Response to Different Thermal Environments

Thermal Comfort. The man is a warm-blooded animal that needs to maintain the internal temperature of the body (brain, heart and organs of the abdomen) in order to survive. Within very narrow limits, at a constant temperature of 37 °C, forcing a constant search for equilibrium between the man and the surrounding environment. It has an influence on this internal temperature, and a slight deviation from this value can lead to death.

When there is the psychological perception of this balance, one can speak of thermal conformation, which is defined by ISO 7730 as "a state of mind that expresses satisfaction with the environment that surrounds a person (neither hot nor cold)." It is therefore a subjective sensation that depends on the biological, physical and emotional aspects of the occupants, and it is not possible to satisfy all the individuals who occupy an enclosure space [4].

Thermoregulation plays a fundamental role in the thermal comfort, since it is a set of mechanisms that allows to stabilize the body temperature of the animals against the thermal variations of the external environment. This process is therefore essential for living beings both in maintaining the rate of cellular metabolism and the integrity of the organism.

Thermal comfort is a concept that cannot be precisely defined. In order to have the same environment with several people in different garments and to practice different activities, it is difficult to conceive a pleasant environment. The comfort zone is not objective because it varies by people and depends on quantifiable factors such as air temperature and humidity, and not quantifiable as habits and mental state.

Well-being, in the context of thermal comfort, means the lack of sensation of hot or cold. When external conditions allows the thermal regulation mechanisms of an individual to be reduced as much as possible, i.e., that the organism is in equilibrium with the surrounding environment, a comfortable thermal environment is achieved [5].

Thermal Stress. Thermal stress, as opposed to the definition of thermal comfort, can be understood as the parameter that tells us when the set of conditions by which the human autoregulation mechanisms are maximal. It can be also defined as the range of thermal limits in which most of the people manifest extreme discomfort, since the human capacities to withstand extreme temperatures are different from individual to individual [6].

Thermal stress, either by high or low temperatures is manifested as a danger since the capacity to ensure human physical health must maintain the internal temperature of the body within limits quite strict, regardless of the variations that may occur in the surrounding environment.

The physiological, psychological and even economic consequences of carelessness in the creation of a thermally qualified environment are of various orders, highlighting the capacity of human beings to adapt is not limitless.

There are six variables that influence thermal comfort and thus stress. The activity performed (M) and the thermal insulation (clo) are the subjective variables. The remaining variables are the so-called environmental variables where the air temperature (T), the radiant temperature average (Tm), the air velocity (m/s) and, finally, the partial pressure of the water vapor in the ambient air (Pa) [6].

The analysis of comfort or thermal stress in a workplace requires the knowledge of physical quantities and characteristics of the considered environment. They are the air temperature, air humidity, air velocity and radiant heat [4]

The aim of this study was to evaluate thermal comfort in a meat processing industry, calculating PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) and identify possible preventive and protection measures in the eventuality of thermal discomfort.

2 Methods

The information gathered to support this research was based on case studies. This methodology helps to understand why certain characteristics are observed in target cases [7]. The applied study was of level I, of the descriptive-exploratory type.

In order to achieve the aim of this research, a thermal environment assessment was carried out taking into account measurements to the followed variables, for all workstations: temperature, relative humidity and air velocity.

The number and duration of measurements were determined so that each measurement was representative of the workplace and/or operation. Thus, measurements were made with the following conditions:

- Definition of measuring points (N = 21), taking into account the established workstations;
- Evaluation of 5 min, for each thermal amplitude;
- Evaluations carried out, whenever possible, with the presence of the worker at the workplace;
- Analysis of each worker's clothing to calculate the clothing thermal resistance index and metabolism;
- Characterization of the physical conditions of the workplace.

The calculation of metabolism (M) and clothing thermal resistance index (Icl) was based on the ISO 7730 (Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria).

For the collection of environmental data it was used the VelociCalc, brand TSI, model 8347-M-GB. It was also used a globe thermometer and a tripod. After the measurements carried out, the PMV and PPD indexes were calculated for a posteriori proposal of preventive/corrective actions.

3 Results and Discussion

Physical Characterization of Space. As a meat-processing industry, the manufacturing plant in all its spaces has a controlled atmosphere. There are no windows or other openings that allows the incidence of sunlight. The walls are lined with tiles. There is a packaging warehouse that has no controlled atmosphere, as well as production offices.

Characterization of Workers. There are no workers in vulnerable situation as identified by the Department of Occupational Health Services. Updated medical fitness records do not evidence workers conditioned.

All workers have vests and protective coats for low temperatures, rubber boots and protective gloves. The worker, who develops his activity in the expedition zone and freezing storage chamber, has his own thermal protection clothing, being considered in this evaluation as: "heavy winter clothing".

Twenty-one sites were evaluated in terms of air temperature, relative humidity, air velocity and globe temperature. In those sites, Metabolism, Chothing Index, PMV and PPD were also evaluated. The results, by work station, can be observed in Table 1.

Table 1. Measurement results, by workplace.

Workplace	Air temperature/ dry bulb (°C)	Relative humidity (%)	Air velocity (m/s)	Globe temperature (°C)	M	Icl	PMV	PPD
1. Production area (next to the horizontal side sealers machine)	12.7	81.9	0.07	14.0	1.6	1.0	−0.67	14.4
2. Production area (next to the press and slicing machine)	15.2	62.3	0.0	16.0	1.6	1.0	−0.36	7.7
3. Freezing tunnel (entrance)	13.3	69.6	0.06	15.0	1.6	1.0	−0.56	11.6
4. Freezing tunnel (exit)	14.1	73.9	0.05	15.5	1.6	1.0	−0.45	9.2
5. Sanitizing machines (exit)	11.9	76.7	0.07	12.0	1.6	1.0	−0.93	23.3
6. Skin removal machine (exit)	12.9	83.8	0.03	12.0	1.6	1.0	−0.84	19.9
7. Band saw	14.9	81.2	0.26	16.5	1.6	1.0	−0.47	9.6
8. Wrapping machine	14.7	78.5	0.09	16.5	1.6	1.0	−0.28	6.6
9. Packaging machine	14.6	79.9	0.21	16.5	1.6	1.0	−4.3	8.9
10. Cutting room (entrance)	11.5	74.9	0.15	12.5	2.0	1.1	−0.37	7.8
11. Cutting room (at the end of the room)	10.6	79.3	0.09	12.0	2.0	1.0	−0.4	8.3
12. Next to the freezing chamber	11.7	69.8	0.22	12.0	2.0	1.5	0.09	5.2
13. Chopped room	17.8	79.7	0.02	18.0	1.6	1.0	0.09	5.2
14. Room next to the chopped room	15.7	63.5	0.01	16.5	1.6	1.0	−0.27	6.5
15. Point of sale (butchery)	21.1	41.1	0.04	22.5	1.6	0.5	−0.05	5.1
16. Point of sale (cutting room)	12.1	63.2	0.2	13.0	2.0	1.0	−0.4	8.3

(*continued*)

Table 1. (*continued*)

Workplace	Air temperature/ dry bulb (°C)	Relative humidity (%)	Air velocity (m/s)	Globe temperature (°C)	M	Icl	PMV	PPD
17. Cardboard warehouse	18.0	69.1	0.0	19.0	1.6	1.0	0.15	5.5
18. Lower floor	16.4	70.3	0.0	17.0	1.6	1.0	−0.12	5.3
19. Management office	16.7	70.6	0.02	17.5	1.4	0.9	−0.58	12.0
20. Offices	16.5	69.0	0.01	17.5	1.4	0.9	−0.6	12.5
21. Main office	25.8	47.7	0.02	26.5	1.4	0.5	0.77	17.5

In practice, given the results obtained in the evaluation carried out, it can be verifiedthe existence of neutral, cold and hot thermal environments. Taking into consideration the type of environment found in each task and the type of industry studied, the following measures can be proposed:

Thermal Neutral Environment. The stations with neutral thermal environment were workstations: 2, 4, 8 to 18.

Considering the type of activity and the thermal resistance of the clothing used, values of PPD below 10% and values of PMV included in the range [−0.45; 0.09], reflected neutral conditions.

It can be verified that, according to the values obtained in the evaluated workplaces, the thermal environment is acceptable, i.e., a situation of thermal comfort.

In relation to the relative humidity of the air, considering the type of activity, the measured values are within the range of recommended parameters.

Cold Thermal Environment. The measuring points 1, 3, 5 to 7, 19 and 20 presents a thermal environment considered cold.

Considering the type of activity and the thermal resistance of the clothing used, values of PPD above 10% and values of PMV included in the inter-value [−0.93; +0.56], reflected slightly cold conditions.

Thus, according to the values obtained in the workplaces, the working environment is within a situation of thermal discomfort, in which statistically 15% of the workers are uncomfortable.

When environmental conditions provide for body heat losses, in addition to those required to maintain its constant internal temperature, the organism reacts by means of its automatic mechanisms - sympathetic nervous system - seeking to reduce losses and increase internal combustion (performed through the endocrine glandular system) [2].

Excessive cold can reduce reaction time, increase tension, cause heart rhythm disturbances, decrease sensitivity, hypothermia, and freeze [1].

When the heat transferred to the environment is higher than the heat received or produced by means of the basal or working metabolism, the body tends to cool down and, to avoid hypothermia (decrease of the body temperature), initiates multiple mechanisms such as blood vasoconstriction (reducing the transfer of heat to the outside); sweat gland closure; decreased peripheral blood circulation; tiritona - heat production (chemical transformation in mechanical/thermal); autophagy of stored fats (chemical transformation of lipids to directly metabolized glycerides: shrinkage: present the minimum surface of skin in contact with the exterior [3, 4].

The consequences of hypothermia can also be highlighted by the general feeling of malaise; decreased manual dexterity, reduced tactile sensitivity; joint ankylosis; extravagant behavior (hypothermia of the blood that irrigates the brain); freezing of limbs (most affected, limbs); chilblains; erythrocyanosis; foot of the trenches; (temperatures below −20 °C). Death occurs when the internal temperature is below 28 °C due to heart failure [3, 4].

Exposure to cold from discovered parts (face, hands) causes an increase in blood pressure and a decrease or increase in heart rate. These two effects are translated by an increase of the work of the heart. For these reasons, individuals with cardiovascular affections should not be exposed to cold, even protected.

Rheumatism appears more often in individuals exposed to cold. It is assumed that it is the variations in the temperature of the mucous membranes that favor the appearance of rheumatism, since the cooling of these favors, in principle, the penetration of virus into the cells [4].

Since that, by the nature of the developed activity, and due to food safety regulations and requirements, the air temperature cannot be increased, it is suggested:

- Provision of personal protective equipment to workers, namely thermal vests.
- Raising workers awareness of the risks they are exposed to;
- Rotativity of workers per job;
- Pauses;
- Ingestion of hot drinks;
- Use of warm clothing.

Hot thermal environment. The only workplace that present hot thermal environment is the corresponding to the number 21 (main office).

Considering the type of activity and the thermal resistance of the garments used, values of PPD above 10% and value of PMV of 0.77 were obtained, reflected slightly hot temperatures.

According to the values obtained in the evaluated place, it is faced the situation of thermal discomfort, in which, 17.5% of workers are uncomfortable.

Regarding the relative humidity of the air, considering the type of activity, it is slightly below the recommended values, in the measurement points 2 to 4.

When the heat losses are lower than those required to maintain the constant internal temperature, the body reacts by means of its automatic mechanisms - sympathetic nervous system - providing more intense heat exchange conditions between the organism and the environment, and reducing combustion (through the endocrine glandular system). The increase in heat losses to the environment occurs through vasodilation and exudation [2].

Excessive heat can cause decreased performance, headaches, nausea, dizziness, sweating, cardiac fatigue, mineral and water imbalance, burns, stimulus-reaction disturbances, and thermal fatigue [1].

In addition to the above-mentioned effects, sweat deficiency is another possible phenomenon. The symptoms consist of a feeling of heat, exhaustion, and the heart rate can increase rapidly and eventually collapse. Also, heat edema (dilatation of the feet and ankles) is another possible scenario, occurring mainly in non-acclimatized individuals. Finally, rashes can occur on any part of the body, but preferably in areas that remain moist (e.g., groin and armpit). In these areas, non-evaporated sweat causes red pimples or irritations of easy treatment, but they can cause infection if not treated [6].

The temperature and humidity of workplaces must be appropriate to the organization and take into account the working methods and physical constraints inherent in the work.

If possible, the risks must be eliminated, preventing working under conditions or climatic factors that exceed the values related to fatigue and thermal discomfort.

Measures of various types are known in terms of limiting the effects of risks [1]:
Design measures

- Ensure the quality of design, acquisition and maintenance of ventilation and air conditioning systems;
- Localized ventilation and aspiration;
- Forecasting the needs of hot air inflation in cold areas.

Organizational measures

- Limitation of exposure time;
- Introduction of rest intervals;
- Selection of the most adequate time periods for the execution of the work;
- Automation of processes;
- Alteration of facilities or the deployment of jobs.

Material measures

- Control of emission sources;
- Replacement of work equipment;
- Protection of opaque walls and ceilings;
- Radiant heat protection screens;
- Protection of glazed surfaces.

Individual protection measures

- Use of personal protective equipment and appropriate clothing.

Medical surveillance measures

- Medical surveillance of workers exposed to aggressive thermal environments.

4 Conclusions

An unadjusted thermal environment can give rise to psychological discomfort and malaise, absenteeism, reduced productivity, increased frequency of accidents and physiological effects.

Most of the evaluated workplaces resulted in neutral thermal environment, existing also several workplaces with cold thermal environment.

By the nature of the developed activity and due to food safety regulations and requirements, air temperature cannot be increased.

This result highlight the importance of design measures, organizational and material measures, alongside individual protection measures and suitable medical surveillance.

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Examination of Occupational Health and Safety Practices in Ghana

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Abstract. Occupational Health and Safety (OHS) issues has been a major challenge to the Ghanaian government. The purpose of the study was to examine OHS practices in Ghana. The study looked at various views from different scholars about OHS practices in order to achieve the objective of the study. Literature review was conducted on OHS in Ghana. Findings from the study shows Ministry of Roads and Transport (MRT) and Ministry of Water Resources, Works and Housing (MWRWH) are two government ministries in charge of construction and implementation of the construction sector policy. The Factories, Offices and Shops Act 1970, Act 328 and the Mining Regulations 1970 LI 665 are the two major edicts. The study presents a strong background on OHS practices in Ghana and contribute to the body of knowledge on the solution to the current trends and challenges of OHS in the construction sector.

Keywords: ILO convention · OHS challenges · OHS practices · OHS improvement

1 Introduction

The existence of several regulatory bodies in Ghana have compounded the Occupational Health and Safety (OHS) challenges [1] and this is plagued with non-ratification of the of the ILO convention 1981 (No. 155). Mustapha, Aigbavboa and Thwala [2] opined that OHS implementation and practice is a major challenge in the establishment of comprehensive national OHS policy in Ghana. Mustapha et al. [3] in their study of Occupational Health and Safety (OHS) Challenges in the Ghanaian Construction Industry recommended that OHS issues should be taken seriously at all levels to deal with the challenges facing the construction sector. Moreover, Mustapha et al. [3] posited that accident would only be reduced in the construction sector through effective OHS management and ratification of International Labour Convention 1981 (No. 155). The paper discussed institutional environment, OHS legislation, regulation setting, International Labour Organisation (ILO) Conventions Ratified by Ghana, ILO Convention 1981 (No. 155), current trends and challenges of OHS in Ghana.

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2 Design/Methodology

The research method adopted is literature study from various studies on OHS in Ghana. The review of literature looked into details on different views from different scholars about Institutional Environment, Occupational Health and Safety Legislation, Regulation Setting, International Labour Organisation (ILO) Conventions Ratified by Ghana, Current Trends of Occupational Health and Safety and Occupation Health and Safety Challenges in Ghana. Few studies out of several studies reviewed on OHS in Ghana were selected due to their relevance. Specific issues relevant to OHS practices in Ghana were selected for analysis from the results of the literature review. Needs for the study are clearly defined and strategies are proposed for their improvement in the OHS practices.

3 Literature Review

This section under literature review provides information in relation to Institutional Environment, Occupational Health and Safety Legislation, Regulation Setting, International Labour Organisation (ILO) Conventions Ratified by Ghana, International Labour Convention 1981 (No. 155), Current Trends of Occupational Health and Safety, Occupation Health and Safety Challenges in Ghana.

3.1 Institutional Environment

The activities of many government ministries and other organisations affect the construction industry of Ghana. The activities of construction businesses and implementation of state policy in the construction sector are under two government ministries: Ministry of Roads and Transport (MRT) and Ministry of Water Resources, Works and Housing (MWRWH). The Ministry of Roads and Transport (MRT) handles the road sector of the economy. Ghana Highways Authority (GHA), Department of Urban Roads (DUR) and Department of Feeder Roads (DFR) are under MRT. The Ministry of Water Resources, Works and Housing (MWRWH) handles policy implementation in respect of works, housing, water supply, sanitation and hydrology and oversees the activities of building contractors. The MWRWH comprises of the Public Works Department (PWD), the Department of Rural Housing, Department of Hydrology, Rent Control Department, and agencies for implementing programmes deriving from government policies. Physical developments, particularly roads and housing are carried out after the relevant departments are satisfied that the project meets the requirements stipulated within the planning and building regulations of Ghana. Environmental concerns have to be addressed by the client and contractor [4].

The activities of other government ministries, departments and agencies that impact on the construction industry as regulators:

i. Ministry of Manpower Development and Employment (MMDE) has the Labour Department and Factory Inspectorate under it. Labour issues and issues relating to employment is the responsibility of the former department while occupational health and safety issues are the responsibility of the latter.

ii. Ministry of Environment and Science (MES) has the Environmental Protection Agency (EPA) and Town and Country Planning under it. The Environmental Protection Agency implements policies relating to the environment and ensures environmental regulations. The Town and Country Planning has the responsibility for ensuring projects comply with zoning laws and building regulations.
iii. Ministry of Health, through its Occupational Health Unit, handles occupational health issues.
iv. Ministry of Lands, Forestry and Mines has relatively many departments and agencies under it, responsible for the use of land and resources. The Lands Commission, Survey Department, Office of the Administrator of Stool Lands, Lands Valuation Board and Land Title Registry have roles that could influence the construction industry [4].

3.2 Occupational Health and Safety Legislation

Occupational Health and Safety (OHS) legislation is a means by which the work environment can be controlled to ensure the safety, health and welfare of employees and persons likely to be adversely affected by the work environment. In Ghana, OHS legislation has been inherited from a British legal and institutional framework at the time when Ghana was a British dependency. The H&S of workers in the mining and wood processing industries of Ghana prior to independence was protected by the Factories Ordinance 1952. This remained the main OHS legislation in force until its repeal by the Factories, Offices, and Shops Act 1970. Regulations made under the Factories Ordinance 1952 which remained enforced include:

i. The Factories (Woodworking) Regulations, 1959;
ii. The Food Factories (Welfare) Regulations, 1959; and
iii. The Factories (Docks Safety) Regulations, 1960 [5].

The Ghanaian OHS legislation is influenced by the International Labour Organisation (ILO). Principal ILO conventions relating to OHS which have been ratified by Ghana include:

i. Underground Work (Women) Convention 1935 (No. 45);
ii. Radiation Protection Convention 1960 (No. 115);
iii. Guarding of Machinery Convention 1963 (No. 119);
iv. Hygiene (Commerce and Offices) Convention 1964;
v. Working Environment (Air Pollution, Noise and Vibration) Convention, 1977;
vi. Labour Inspection Convention 1947 [5].

Existing OHS legislation in Ghana is fragmented and limited in coverage. Some key economic sectors are not covered by the country's OHS laws. A notable example is the agricultural sector, although it employs over 60% of the country's workforce. There is no form of OHS laws regulating the activities of the construction sector. This unfortunate situation can be traced back to colonial rule in Gold Coast (Ghana), where the colonial government placed more emphasis on labour relations in sectors of the economy where formal employment relations existed. The mining and manufacturing sectors of the economy are examples of such economic sectors [5].

3.3 Regulation Setting

The Labour Act No 651 of 2003 consolidates and updates the various pieces of former legislation, and introduces provisions to reflect ratified ILO Conventions. The Labour Act covers all employers and employees except those in strategic positions such as the Armed Forces, Police Service, Prisons Service and the Security Intelligence Agencies. Major provisions of the Labour Act include establishment of public and private employment centres, protection of the employment relationship, general conditions of employment, employment of persons with disabilities, employment of young persons, employment of women, fair and unfair termination of employment, protection of remuneration, temporary and casual employees, unions, employers' organisations and collective agreements, strikes, establishment of a National Tripartite Committee, forced labour, occupational health and safety, labour inspection and the establishment of the National Labour Commission [6]. Employers are therefore obliged to provide training for their employees for the attainment of the level of competence required for the performance of their jobs and to enhance their career [6].

3.4 International Labour Organisation (ILO) Conventions Ratified by Ghana

Ghana joined the International Labour Organisation (ILO) in 1957 and immediately the Convention Peoples Party (CPP) Government ratified many of the ILO Conventions including the 'core' Conventions that guarantee workers the right and freedom to form or join unions (Convention No. 87), the right to collective bargaining (Convention No. 98), abolition of forced labour (Conventions Nos. 29 and 105), and equal treatment (Conventions Nos. 100 and 111). Many other ILO Conventions that sought to promote industrial harmony and welfare of workers were also ratified. These included Conventions on hours of work in industry, weekly rest, minimum wage fixing, labour inspection, underground work by women, employment service, night work by women, social policy, working environment, child labour, labour administration, and many others. Ghana has so far ratified 46 ILO Conventions [6].

3.5 International Labour Convention 1981 (No. 155)

The ILO convention, 1981 (No. 115) is important due to some fundamental ideas and ways of carrying out activities put in place for OHS management improvement. It introduces interrelated activities of a national policy to OHS. The national OSH policy gives a framework to reduce hazards at workplace and this should be formulated, implemented and reviewed yearly. Article 7 of the Convention indicates that the formulation, implementation and yearly review of the national OSH policy should be done through identification of major problems and provide methods that are effective. Since the aim of the policy and under Article 4.2 of Convention No. 155 is prevention of accident and injury at workplace. Hence, the national OSH policy should enforce the ILO convention, 1981 (No. 115) towards OHS improvement [7].

3.6 Occupational Health and Safety Trend in Ghana

Currently, there two major edicts that provide guidance for occupational or industrial safety and health services, practice and management in Ghana [1, 8]. These include the Factories, Offices and Shops Act 1970, Act 328 and the Mining Regulations 1970 LI 665. The presence of Workmen's Compensation Law 1987 (PNDC 187) has direct impacts on monitoring worker or workplace safety. Statutes that indirectly impact on OHS include Environmental Protection Agency Act 490 1994, the Ghana Health Service and Teaching Hospital Act 526, 1999 and the National Road Safety Commission Act 567 1999 [8].

Ghana is among the 183 member countries of ILO, which requires, as per the ILO convention number 155 1981, that member countries formulate, implement and periodically review a coherent policy on OHS and work environment. Ghana is yet to rectify this convention and has not established authority dedicated to OHS to guide and facilitate the implementation of the "Action at the National Level" as indicated in the R164OHS recommendation, 1981 [1, 8]. However, the Labour Act 2003, Act 651, Part XV, sections 118 to 120 apparently directs employers and employees in their roles and responsibilities in managing OHS and Environment in the nation. However, it is not clear what to consider as Occupational Illness and who handles the implementation of corrective actions as per recommendations. Currently, accidents that occur in factories are expected to be reported to the Department of Factory Inspectorate (DFI), but companies hardly report such events to the inspectorate for investigation and correction. Hence, there is a little or no positive effect of the action of the DFI on the factories [8].

3.7 Challenges of Occupation Health and Safety in Ghana

The Ghanaian Government has been facing challenges in the Occupational Health and Safety (OHS), plagued with its inability to ratify the International Labour Organisation (ILO) convention, 1981 (No. 155). This development has affected the construction industry as indicated by [1]. Kheni et al. [4] asserted that inadequate government support for regulatory institutions and lack of skilled human resources were among the challenges of OHS in Ghana. Dadzie [9] posited H&S training deficiency, inability to assess danger and workers reluctant attitudes towards H&S. Human resources development and inadequate OHS capacity for the industry has been indicated as some of the challenges [10]. Even though, the concept of OHS in industries was conceived in Ghana before the introduction two major edicts [1] The existence of some fragments of OHS legal requirements under jurisdictions of different agencies in Ghana has led to the OHS challenges in Ghana [1].

4 Lessons Learnt

The following are the lessons learnt from the study of the Examination of Occupational Health and Safety Practices in Ghana. The activities of construction businesses and implementation of state policy in the construction sector are under two government ministries: Ministry of Roads and Transport (MRT) and Ministry of Water Resources, Works and Housing (MWRWH) are two government ministries which supervises construction and implementation of the state policy in the construction sector. Two major edicts that provide guidance in the provision of occupational or industrial safety and health services, practice and management in Ghana are The Factories, Offices and Shops Act 1970, Act 328 and the Mining Regulations 1970 LI 665. This OHS legislation are protected by the Factories Ordinance 1952. These include the Factories (Woodworking) Regulations, 195 9, the Food Factories (Welfare) Regulations, 1959; and the Factories (Docks Safety) Regulations, 1960. The Labour Act No 651 of 2003 consolidates and updates the various pieces of former legislation and introduces provisions to reflect ratified ILO Conventions. The Labour Act covers all employers and employees except those in strategic positions such as the Armed Forces, Police Service, Prisons Service and the Security Intelligence Agencies. The construction sector lacks OHS regulations. Hence, the adoption of the ILO convention 1981 (No. 115) as the OHS policy in Ghana should be encouraged.

5 Conclusion

The purpose of the study was to examine Occupational Health and Safety (OHS) Practices in Ghana. The non-compliance with H&S rules and regulations in the Ghanaian construction sector is as a result of non-ratification of the ILO convention 1981 (No. 115). This has resulted to the major issues facing the construction sector, in addition to occurrences of injuries and accidents. This development is a major blow to most of the institutions in Ghana because there is no standard degree meant for OHS for the construction sector Therefore, the call for proper development of H&S policy for the construction sector in Ghana.

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Safety and Ergonomics

Smart Phone Use and the Increased Risks of Cumulative Trauma Disorders in Children

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Abstract. The prevalence and use of portable electronic devices have contributed to the sedentary lifestyle of children. When used, these devices often cause children to remain in astatic posture for minutes and even hours within a day. This study investigated the possible effects of smart phone use on the musculoskeletal system of children. The focus was on children 10 to 12 years of age. Nine participants and parents completed a questionnaire. A goniometer was used to measure neck flexion and a measuring tape was used to measure viewing distance. While all participants reported feelings of discomfort after using a cell phone, all parents reported their child never complained of any discomfort. Seven of eight children identified feelings of pain in one or more body regions. Neck flexion ranged from 3° to 56°. Findings raise concern about the increased risks of children developing cumulative trauma disorders.

Keywords: Smart phones · Neck flexion · Musculoskeletal disorders · Viewing distance · Static posture

1 Introduction

In 2013, 2.32 billion devices (personal computers (PCs), tablets, and cell phones) were projected to be sold worldwide [1]. Sales were expected to increase to approximately 2.49 billion devices in 2014. While PC sales were expected to decline, the sale of tablets and cell phones were expected to continue to rise. Of the more than 2.32 billion devices sold in 2013, cell phones accounted for approximately 1.8 billion (78%) [1]. The cell phone has become the device that many take with them not just when traveling, but also to dinner table, restrooms, and even to bed [2]. Most of these portable devices are sold to adults for their own use or for their children. Whether the intended user is an adult or a child, children, as young as three, make up a high percentage of users of cell phones and tablets [3–5]. However, one does not have to look too far to see that toddlers, even babies as young as nine or ten months old are using the devices. In fact, children are consistent, daily users of these devices for long periods of time as they are lightweight, portable, and contain simple interfaces.

The increased use of cell phones and other electronic devices has led to a growing concern, by researchers and others, about the impact of these devices on the health of children. The high use of cell phones by children, 10 mo. or younger to age 17, has led

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to a call for precaution. There is a community of researchers who believe there is a causal relationship of cell phone use to cancer; primarily in the form of brain tumors resulting from exposure to and absorption of microwave radiation in children [6–9]. There has been no convincing evidence of this link [10, 11].

The proliferation of portable electronics has contributed to the sedentary lifestyle of adults and children. When used, these devices cause the user to remain in static postures for minutes and hours within a day, with eyes fixed to a screen. This has led to the study of computer visual symptoms (CVS) with smart phone use. Viewing the small screens of smart phones necessitates close working distances which may induce various symptoms such as dry eyes, fatigue, headaches, eyestrain (asthenopia), presbyopia, etc. [12–15]. Berolo et al. [16] and Kim [17] studied the musculoskeletal symptoms and neck posture of users of mobile hand-held devices and smart phones, respectively. Each found that a neutral neck posture was altered. The static postures of smart phone users is not unlike those seen by users of computer display monitors or even in professions such as dentistry where a load is placed on the neck and back [18–20]. Per the international standard, ISO 11226 [21] which evaluates the static working postures, neck flexion of 0°–25° is acceptable as long as there is variation in the task. However, the use of smart phones lends itself to little to no variation in tasks.

Much of what is known to date on the impact of smart phones is based on studies of adults. Little is known about the effect of the use of electronic devices on the musculoskeletal system of children. This research focuses on the impact of smart phone use and possible relationships to increased risks of the development of cumulative trauma disorders in children. Neck flexion and viewing distance are measured.

2 Method

2.1 Participants

Nine participants were recruited from the Peoria, Illinois metropolitan area; five females and four males. Two of the participants participated in the observational study. The children ranged in age from ages 10–12, with a mean age and standard deviation of 11.67 (±1) years. Mean height and standard deviation were 58.5 (±3.64) in, with a mean (SD) weight of 95.73 (22.78) lb. The mean grade of the participants was 6.33 (±1.41). Eight of nine participants were right handed and three of the nine had corrected vision. All participants were in good to excellent health and none were currently under or previously under a doctor's care for a musculoskeletal disorder in the last 12 months. Both participants and their parent or guardian provided written consent to participate in the study. Upon completion of the study, each participant was given $20 for compensation. The study was approved by the university's Committee on the Use of Human Subjects in Research.

2.2 Experimental Design

The experiment involved the independent variables device (smart phone) and position (seated on sofa (SS), seated in a chair (SC) at a desk, and seated on the floor (SF) on a rug). An additional position was called personal choice. For personal choice, the participant could select any of the three seated positions. There were two dependent variables – viewing distance and neck flexion. Personal choice was always performed first. The other three trials were run in random order. This study is part of a larger study which involves an additional device and additional trials. Descriptive statistics were performed.

2.3 Equipment

For this study, a plastic 12 in, 360° ISOM (international standard of measurement) goniometer with a scale of 1° increments was used to measure neck flexion. A 60 in./150 cm soft cloth measuring tape was used to measure the viewing distance. Viewing distance was measured as the distance from the eye to the smart phone screen. All participants were given a Nexus 5× 16 GB smart phone loaded with age appropriate games (such as Angry Birds, Subway Surfer, Jet Pack, Crossy Road, etc.) to play during each trial. Two questionnaires were developed by the researcher using the ©2017 Qualtrics LLC survey tool – one for the parent and another for the participant. Two Sony Handycam CX440 camcorders were used to record each session.

2.4 Procedure

Prior to the start of the experiment, both the parent and the participant signed the consent form and were given their respective questionnaires. With the exception of one parent and two children who completed paper copies, the questionnaire was completed on line using the Qualtrics software. A link to the parent questionnaire was sent to the parent's email address. Demographic data was collected from the participant and the trials were conducted in randomized order, excepting the personal choice trial. Each child had the option to choose from the preloaded games on the device and play a game(s) of his/her choice. Each trial lasted two minutes, with a recovery period of one minute between each trial. Measurements were taken at approximately the one minute mark.

3 Results

3.1 Questionnaire Results – Daily Use and Musculoskeletal Symptoms

All nine participants reported some daily use of the smart phone. Parents reported applying time restrictions to the use of the smart phones and indicated the use of the device to be less than one hour per day. Seven of the participants reported using the smart phone for two or more hours per day, with one reporting more than four hours per day. See Table 1 for the estimated daily use. It is important to note that additional hours each week can be or were spent, as reported, playing or interacting with other electronic devices (such as a Wii, Xbox, PlayStation, iPod, tablet, or the computer).

Table 1. Child and parent reporting for daily use of smart phones

	Restricted use	Estimated daily use (h)			
		<1	≥1 but <2	≥2 but <4	≥4 but <8
Participant	–	2		6	1
Parent	Yes	8[a]			

[a]There were a total of 8 parents, as one parent accounted for 2 children

When asked if their child ever complained of any body areas of discomfort or pain after use of the phone, all parents responded that their child never complained of discomfort or pain related to cell phone use. However, when shown the body diagram in Fig. 1, seven of eight participants indicated they felt discomfort or pain in certain body regions related to smart phone use. Data was not available for one participant. Discomfort/pain was most prevalent in the neck (See Fig. 2) with six of eight (75%) identifying discomfort/pain in this body region. In both the upper back and the wrist/hand/fingers areas, three (37.5%) people reported discomfort/pain. Two people also reported headaches related to the use of their smart phones. A mean (SD) of 2.25 (±1.58) musculoskeletal symptoms were reported. In all cases, except one, the reported pain was moderate. For the one exception, the participant described the neck pain as severe. No one identified any musculoskeletal symptoms in the lower extremities.

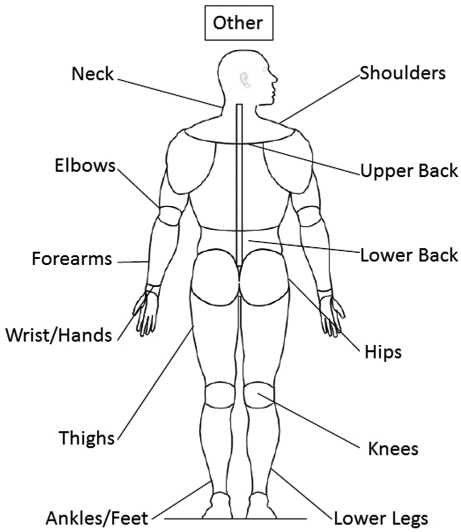

Fig. 1. Body region diagram. (adapted from [22])

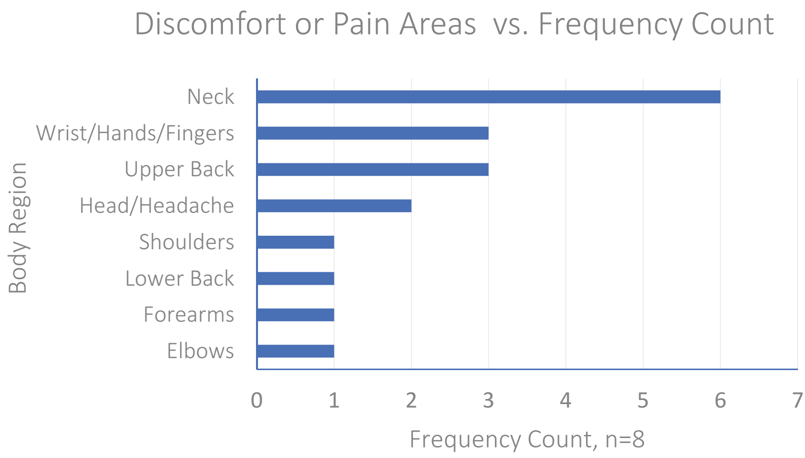

Fig. 2. Participant reported musculoskeletal symptoms

3.2 Neck Flexion and Viewing Distance

As the participants performed the four trials, neck flexion and viewing distance were measured for each of the trials. When given a choice to select a seated position, five participants chose the sofa, three chose to sit on the floor (on a rug), and one chose to sit in the chair at the desk. The mean (±SD) and range for each of the positions is shown in Table 2 for viewing distance and neck flexion.

Table 2. Participant viewing distance and neck flexion

Position	View distance		Neck flexion	
	Mean (±SD)	Range	Mean (±SD)	Range
Personal choice	14.88 (±3.87)	9.00–21.00	26.14 (±17.19)	3.00–53.00
Sitting in chair	13.99 (±2.58)	9.80–16.60	25.86 (±15.48)	8.00–44.00
Sitting on floor	13.45 (±2.58)	9.00–17.60	26.86 (±16.64)	10.00–56.00
Sitting on sofa	14.14 (±2.95)	10.30–19.50	29.14 (±15.58)	12.00–51.00
Min	9		3	
Average	14.11		27	
Max	21		56	
Mode	16		22	
Median	14		22.5	

The mean viewing distance varied by a maximum of 1.4 in for the four trials and ranged from nine to 21 in. The shortest range was seen when participants were seated in the chair. In this position, the forearms often rested on the desk. (Note: In two instances, viewing distance and neck flexion data were not available for Participants 1 and 2.)

The range of neck flexion for the nine participants was from a minimum of 3° to a maximum of 56°. The lowest range of neck flexion was seen when participants were seated in the chair. Lower degrees of neck flexion were seen when participants were seated in the chair with the back and head supported by the backrest of the chair. Minimal differences were seen between the mean (±SD) of the different positions. In Fig. 3 the viewing distances and neck flexions, for each participant, are shown for the seated in chair position. A participant with a neck flexion of 8° and another with neck flexion of 43° each had the same viewing distance of 16 in. The same type of relationship held true

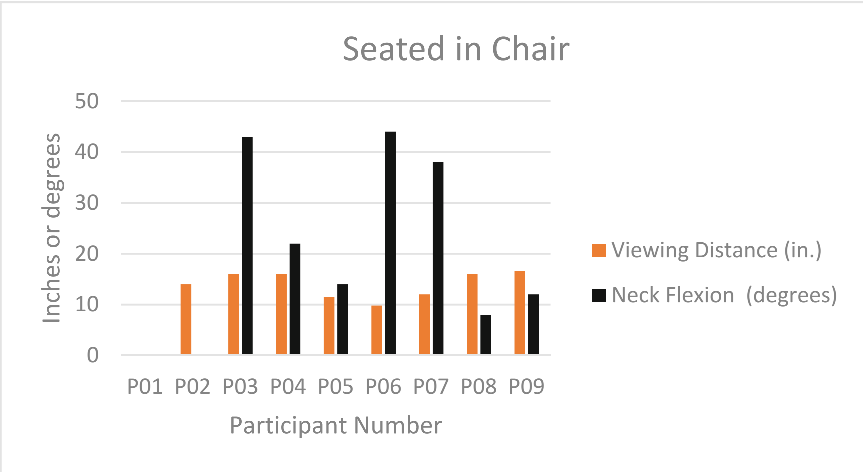

Fig. 3. Participant viewing distance and neck flexion while seated in chair

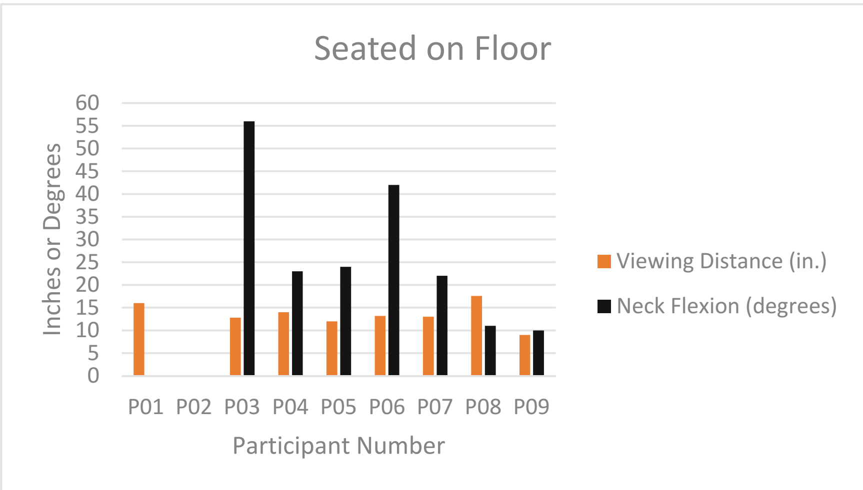

Fig. 4. Participant viewing distance and neck flexion while seated on floor

for the seated on floor (Fig. 4), seated on sofa (Fig. 5), and personal choice (not shown) positions.

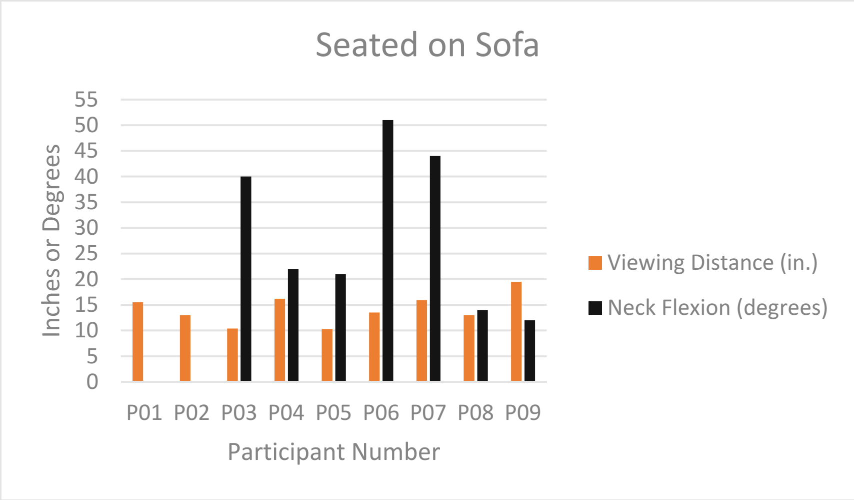

Fig. 5. Participant viewing distance and neck flexion while seated on sofa

4 Discussion

It was determined, via self-reporting, that parents and children, on two separate occasions, held contrasting views. While parents reported placing some restrictions on the use of phones each day, the parents' estimation of the number of hours of use of the device was in most cases less than those reported by the child. The parental reports of less than one hour per day of smart phone use, was in agreement with only two of the nine children. Seven of the nine children in this study reported spending at least two or more hours per day using their cell phones. Another area where parents differed from their child was the reporting of musculoskeletal symptoms. Per each parent, the child never complained of any discomfort or pain related to the use of the smart phone. This led parents to believe no pain or discomfort associated with cell phone use. Yet, in response to this same question, all but one child readily identified one or more regions of pain. The highest reports were of four and five areas of pain with the mean of 2.25 (±1.58) per person. This contrast in responses reveals a gap in what children report about their health and what parents perceive as potential problems due to a lack of reporting by their child.

While using these devices, the user remains in a static posture with the neck flexed. Regardless of the position while using the smart phone, the range of viewing distance and range of neck flexion varied minimally. Per ISO 11226 [21], as long as there is variation in the task, neck flexion of 0°–25° is acceptable. Therefore, it would appear at first glance that for the participants for whom the neck flexion data was available, only three participants would be considered at risk for developing a musculoskeletal disorder;

as their neck flexions exceeded 25°. For one participant, neck flexion exceeded the acceptable limit by at least 15° for all four trials. For another, acceptable limits were at least 10° above the acceptable limit for each trial, and for the third person, the limit was exceeded by 10° for three of four trials. Though the other participants were within the acceptable limit for neck flexion, duration, frequency, and lack of variation in tasks, puts these participants at risk of developing a musculoskeletal disorder.

Participants in this study reported using smart phones for uses other than phone calls. These devices were used to view social media, Instagram, for texting, for playing games as in this study, as well as other uses. When compared to Bilton's [23] proposal of adopting a viewing distance of one foot (30 cm), five out of nine (55.5%) of the participants were consistent in doing so. However, 14.7% of the time or in five instances, two by the same individual, the one foot viewing distance was violated. In these cases, the phone was held as close as nine inches from the user. These occurrences of close, prolonged viewing could contribute to increased instances of dry eyes in children, asthenopia, and/or lead to the acceleration of presbyopia which is usually seen in people 40 and over.

Early findings from this limited study of this young population provide preliminary evidence of an increased risk of developing a cumulative trauma disorders at a young age. Parents and other caretakers will likely need to observe, note and ask the child about possible areas of pain or discomfort during and after smart phone use. The researcher does realize that too many questions could make some children less truthful, if they sense enjoyed privileges could be reduced. It is likely that children 10–12 years of age, and even older, do not understand the repercussions of the symptoms reported. At the very least, children should be encouraged to also participate in activities that do not require a static posture. Children should also be encouraged while using smart phones to periodically pause and refrain from looking at the device and to engage in some stretches or exercises for the neck, shoulders, back and hands.

5 Conclusion

This study identifies the potential of increased risks of developing cumulative trauma disorders, due to daily, prolonged, smart phone use. A gap in reporting of musculoskeletal symptoms by children, an inability to identify or perceive postural issues by parents, prolonged neck flexion, and the close viewing distances can all lead to increased risks and the earlier onset of cumulative trauma disorders of the musculoskeletal and ocular system of children. Though this study focused on 10 to 12 year olds, smart phones are not just used by children starting at the ages 10-12, but these phones are used by children much younger, including toddlers and babies, for prolonged periods of time. Though this study is limited by a small sample size, its findings encourage continuation of the study to further validate the current results. Until further studies can confirm these findings, parents and other caretakers of children should take some precautions. All should be vigilant in watching for musculoskeletal and ocular symptoms in children and encourage activity that does not involve static posture.

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Ergonomic Assessment Tool for Real-Time Risk Assessment of Seated Work Postures

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Abstract. This paper presents a posture assessment tool which utilizes the depth sensing techniques of a 3D imaging sensor for ergonomic risk assessment of seated worker's postures during controlled manual handling tasks. The tool, which has been developed to utilize the manual handling guidelines by the Health and Safety Regulators of some selected countries to measure and assess the postures of the upper bodies of Operators, is tested to ascertain its effectiveness in assessing seated postures. The tool offers real-time posture assessment with real-time feedback to inform Operators on when to adjust awkward seated postures. An experiment has been performed to record, assess and display the work postures of some seated Operators in real-time with 'Good' and 'Awkward' postures identified with real-time feedback provided to the Operators. Results show that the tool can assess seated work postures in real-time which helps to reduce the rate of occurrence of Work-Related Musculoskeletal Disorders.

Keywords: Microsoft Kinect · Awkward postures · Work-related musculoskeletal disorders · Seated workers

1 Introduction

Manual handling tasks involving reaching, lifting, and assembly tasks sometimes require workers to sit throughout the day. Prolonged sitting as well as poor seated postures has been found to be among the leading causes of low back pain and consequently, Work-Related Musculoskeletal Disorders (WMSDs) [1–4]. The sitting posture has been identified as the worst body posture that exists because it forces the spine to adopt a non-natural posture which negatively affects it [5]. This is further explained by the fact that as the hips turn, greater pressure is applied on the spine when the trunk is bent forward, thereby leading to backaches and injuries [6].

Hence, maintaining good seated posture while working do not only improve efficiency, but also protects the worker's health [7]. Again, providing highly adjustable furniture along with adequate training of the users is a key requirement for ergonomic interventions of seated workers [4, 8]. Various international standards such as the ISO 5970:1979, have established recommended chair and table sizes with respect to the

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height of the user [9] and chairs with high backrests can reduce the likelihood of low back pains [3, 6]. The ANSI/HFES 100-2007 standard by the Human Factors and Ergonomics Society recommends adjustable seat pan angles 0°–4°, seat pan backrest of not less than 90° and seat pan recline not exceeding 25° from the vertical [10]. Good seating involves fitting the chair and desks within the body limits of the user and seats should vary depending on task demands [11].

This paper therefore focuses on the use of a developed Health and Safety (H&S) compliance posture assessment tool which utilizes a 3D imaging sensor for the real time measurement, analysis and risk assessment of the work postures of seated workers during manual handling activities.

2 Review of Methods for Posture Measurements of Human Body

Work postures, if awkward, can lead to WMSDs among workers on the shop floor [12, 13]. Measuring posture movements has been found to be very important for determining the risk of WMSDs in the workplace [14] and the methods for assessing these risks depends on the accuracy and precision of the data collection techniques employed [15]. For posture measurements, the reference point is described by the H&S Regulators as the neutral position which occurs when all the joints of the body are naturally aligned, with the trunk and head upright, arms by the side and forearms hanging straight or at a right angle to the upper arm, while the hand is in the handshake position [16–18]. Any deviation from the neutral position beyond the recommended limit often results in awkward postures. This posture can be detrimental to the health when held for prolonged period, hence, the need for a real-time assessment and feedback using appropriate tools with real-time capabilities, so as to inform the operators to adjust any awkward postures they adopt while working.

Research has revealed the existence of several tools developed for measurement of seated work postures. The Computer-assisted recording and long-term analysis of musculoskeletal load (CUELA system), a posture measurement tool developed by the German IFA [19], has been used to measure the body postures of seated Vehicle operators [2]. The system however, does not conduct risk assessment of these postures. Other tools available for measuring human postures include the Ovako Working Posture Assessment. System [20], the force plate [21, 22], photography [15, 22], tape, sensors [23], Microsoft Kinect etc. Photographs and videos often produces inaccurate measurement of joint angles as a result of distortions caused by camera placement issues [15]. Video camera alone cannot be used for posture data measurement, rather, the data obtained needs to be further analyzed using appropriate postural assessment tool [24].

A 3D marker-based measurement system and electromagnetic tracking system can be used to measure the relative angles of the upper bodies of seated workers [23, 25]. This tool can aid posture data collection and analysis in finer details [21]. Inclinometers based on triaxial accelerometers can be used to measure the flexion, extension and lateral extension angles of the human head and upper arms [26]. A photogrammetric analysis method can aid posture data measurements by measuring the joint angles of the upper extremities of the human body [27]. Models of cards has been used for recording seated dynamic work postures [20]. However, the afore-mentioned tools are either marker-based and as a result are required to be worn by the operator, or they lack the real-time feedback capabilities which can help to ergonomically improve worker's postures.

Microsoft Kinect has been recommended as an alternative method for posture measurement because of its cost-effectiveness, 3D motion capture and awkward posture classification capabilities [14, 15, 22, 28]. The sensor can measure human joint angles and can compute joint angles for possible posture evaluations and analysis [15, 21, 29, 30]. It has been proved to be a suitable tool for fast and reliable estimation of human morphology [31].

This paper focuses on the use of a Kinect-sensor-based, non-invasive posture assessment tool, developed by the authors, to measure as well as conduct ergonomic assessment of seated work postures of Operators with real-time display, in compliance with the H&S Guidelines of different countries.

2.1 Recommended Guidelines While Seating to Undertake Manual Handling Tasks

The recommended ergonomic seating practices of the selected Countries are highlighted in this section.

2.1.1 United Kingdom's Health and Safety Executive [4]

The seating recommended guidelines by the UK HSE for safe manual handling activities include:

- Avoid awkward stretching and twisting by placing objects within the recommended reach distance of −0.6 m to +0.6 m along the horizontal plane.
- Ensure the workplace is well lighted to avoid adoption of awkward postures by the workers.
- Adjust the seat to enable you sit comfortably depending on the task.
- Avoid sitting to lift because it strains the back. If not, keep the object to be lifted close to the body.
- Work surface thickness of about 0.03 m should not be exceeded.
- Avoid bending and twisting while sitting to handle rather place the load/materials at waist height on a rack.
- Avoid sitting to handle heavy loads.
- Weight of load to be handled while seated should not exceed 3 kg for women and 5 kg for men.

The following seat dimensions should be ensured;

- Adjustable seat height of 0.38 m to 0.56 m.
- Well-padded sitting surface of about 0.4 m.
- Backrests with adjustable tilt angle of +5° to −5° and 90° to 110° angle with the sitting surface at adjustable height of between 0.17 m and 0.3 m.
- Adjustable armrests of 0.2 m to 0.25 m if needed (some jobs may not require armrests).
- Footrests for workers who need them.
- Chairs should pass the test stipulated in BS 5459 to be suitable for use.

2.1.2 United States of America's Occupational Safety and Health Administration [32–36]

- OSHA recommends that Operators should avoid sitting to lift
- Avoid bending while seating in a static position.
- Avoid excessive reaching while seating.
- Height adjustable chairs or stools with adjustable lumber supports should be provided.
- Footrests should be provided when needed or the feet should rest flat on the floor.
- Backrests, which support the natural curvature of the spine should be provided.
- Armrests must be soft and should enable the elbows to stay close to the body.
- Operators should be trained on the ergonomically correct handling practices, proper use of all equipment, safety precautions and recognition of hazards.
- Use ergonomically designed hand tools that enables straight wrists.
- Ensure the elbows are held close to the body while handling or are bent between 90° and 120°.
- Avoid tilting the head rather use tilt work stations.
- Do not bend the neck instead use height-adjustable workstations.
- Take frequent breaks.
- Ensure the back is always supported.
- When seated to handle, the knees must be about the same height as the hips.
- The hips and thighs should be supported by a well-padded seat and parallel to the floor.
- Employers should provide highly adjustable chairs for multiple users.
- The chairs must have a five-leg base with casters for adequate support.

2.1.3 Germany's Federal Institute for Occupational Safety and Health (BAuA) [5]

- Chairs should be height and depth-adjustable with minimum depth of 0.38 mm as recommended by EN 1335.
- Movable armrests of at least 0.2 m length, 0.04 m width and 0.2 m to 0.25 m height should be provided.
- Backrests should have at least 0.36 m wide and 15° backward inclination reaching the shoulder.
- Adjustable neck support should be provided.
- Sitting surface should be inclined forward with the front edge radius $\leq$0.06 m.
- Adjustable seat heights that makes room for at least 90° angle between the thighs and the calves should be provided.
- Footrests of at least 0.45 m wide and 0.35 m depth is required for short workers.

2.1.4 Singapore's Workplace Safety and Health Council [37, 38]

- When seated to work, the feet should be flat on the floor or supported by a footrest to reduce pressure on the thighs.
- The chair should be adjustable, stable and fitted with removable armrests and footrests.

- Backrests of 100° to 120° height/tilt should be provided.
- Adjustable work surface should be provided in such a way as to suit the needs of every worker.
- The recommended height of the chair should be between 0.35 and 0.5 m while the width should be the dimension of the worker's hip +0.5 m which is approximately 4.6 m in women. The depth should be between 0.38 and 0.43 m.
- Hand tools should be ergonomically designed to minimize workers adopting awkward hand and arm postures.
- The physical environment, which include temperature, lighting and noise, should be conducive.
- To avoid excessive reaching and overstretching, more frequently used objects should be placed within the primary reach zone while less frequently used items are placed within the secondary reach zone.
- Sufficient room should be provided under the worktable for easy movement of the knees and legs.
- Do not handle heavy loads while seated.
- Group all the items that are frequently used together on the workplace.
- Avoid prolonged sitting. Always change postures.

3 Methodology

In this section, we discuss how the developed H&S compliance posture assessment tool was utilized to assess the postures of the upper bodies of seated Operators. A total of ten (10) seated Operators were tested while carrying out different manual handling activities. There were 7 males and 3 females whose age range from 25 to 35 years. None of the participants was unhealthy or had a case of back pain or injuries at the time of the experiment.

3.1 Overview of the Developed Posture Assessment Tool

The developed tool consists of Microsoft Kinect sensor and a developed software application which enables the sensor to capture, analyze and assess the postures of workers during any manual handling operation. It is capable of carrying out ergonomic assessment in real-time and in compliance to the H&S guidelines.

The assessment tool was developed through appropriate codes written in C# Programming Language and which uses the APIs provided by the Kinect for Windows SDK and the WPF Application of the .NET Framework 4.5 in Visual Studio [39]. The algorithm enables the Microsoft Kinect to record the joint angles of seated Operators and display same in real-time.

The first step in the development of the tool was the computation of the vectors for each joint which triggered the joint angle measurement, using Eq. (1). The reference point which is the neutral position was then established such that any deviation from the neutral position results in awkward postures according to the recommendations of the H&S professionals.

$$\theta = A \cdot B\, COS^{-1} \Big/ |A||B|. \qquad (1)$$

The flow chart below shows how the developed tool assesses seated work postures in compliance with the H&S guidelines.

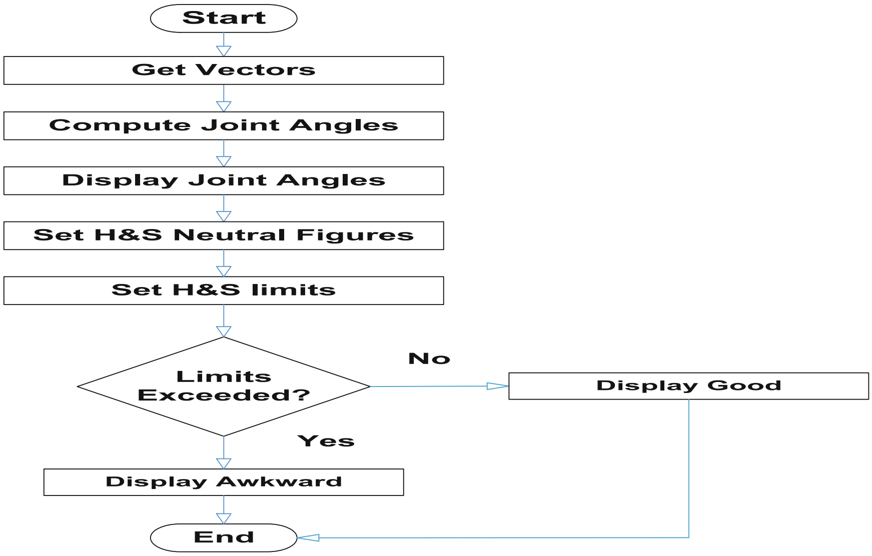


Fig. 1. Developed tool's flow chart

3.2 Procedure for Testing the Developed Tool

Participants were asked to handle a 1 kg load under different ergonomic conditions while seated. These include far and normal reaching, bending to lift, bending and twisting, turning etc. Before starting the experiment, the participants were first familiarized with the manual handling regulations on safe handling techniques so as to avoid the risk of sudden injuries.

During the experiment, the neutral position of each participant was tracked using the sensor after which the rate of deviation of each joint from the neutral position is assessed with the result displayed in real-time to the participants. The chair used for the experiment was carefully selected to meet the H&S recommended standards for chairs, as described in Sect. 1.

4 Results

4.1 Tracking the Neutral Position

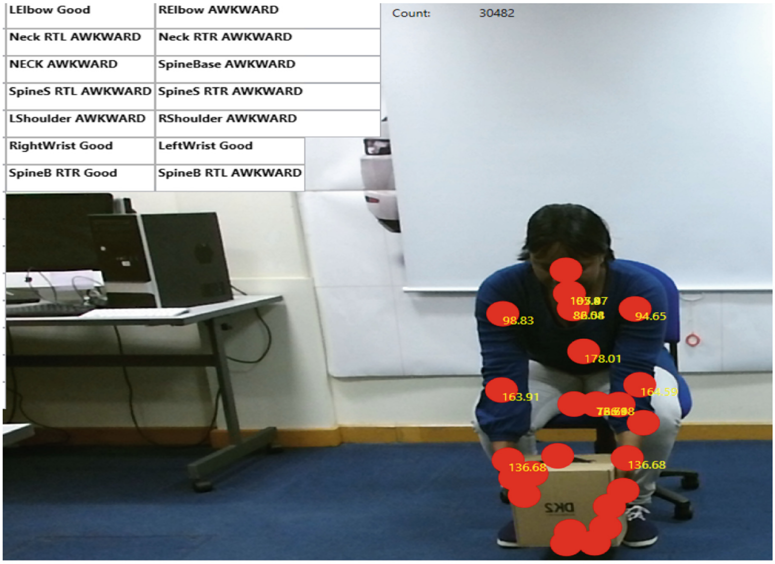
H&S Professionals have established that awkward posture occurs when a part of the body deviates from its neutral position or its natural alignment and a neutral position is when the joints are naturally aligned with the trunk and head upright, the arms by the side, and forearms hanging straight or at a right angle to the upper arm, while the hand is in the handshake position with the wrists not bent or deviated and the buttocks and back are supported [16–18, 33, 40, 41].

Figure 2 shows the result obtained from tracking the neutral position of a seated participant. Notice that all the joints are specified as “Good” and displaced to a worker in real-time.

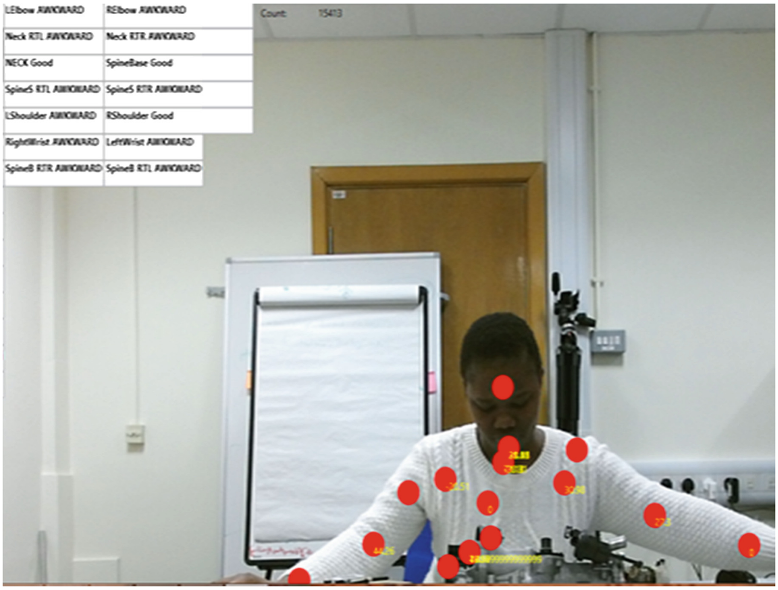
Fig. 2. Neutral position for seated human as specified by the tool

4.2 Tracking Deviations from the Neutral Position

In order to assess the tool further, deviations from the neutral position were simulated as shown in Fig. 3. The results show that the tool is capable of detecting awkward positions and can provide a real-time display of the assessed posture towards enabling a worker to adjust possible awkward postures.



a. **Sitting to lift**



b. **Reaching to Pick while seated**

Fig. 3. Sitting to handle

5 Discussion

The study is limited to posture assessment of the upper body of seated Operators. Having studied the manual handling guidelines as recommended by various H&S professionals, the relevant definitions are used to develop a posture assessment tool using 3D imaging sensors. The first step in the experiment was to ensure that the chair provided meets the standards as specified by the H&S professionals and highlighted in Sect. 1.2. Next, the neutral posture of each participant was tracked as in Fig. 2. Finally, the deviations from the neutral position of each of the joints are assessed by the tool and displayed to the participants in real-time.

In Fig. 3a in which the Operator is bending to lift while seated, the left elbow, right and left wrists, and right hips (SpineB RTR), are displayed as 'Good'. This means that the specified joints have not exceeded the recommended limits as at the time of the capture. Every other joint, including the back posture (SpineBase), are displayed as 'Awkward'. This is in agreement with the UK HSE regulation that operators should avoid sitting to lift as it strains the back.

Figure 3b shows an Operator sitting to pick. The location of the items on the work table forced her to extend her left arm. Therefore, even though she did not flex/bend her back and neck beyond its neutral position (SpineBase and Neck = 'Good'), her elbows, wrists and left shoulder were stretched further away from their neutral positions resulting in 'Awkward' posture display for these joints. This real-time display can enable the Operator to adjust awkward postures so to minimize the likelihood of WMSDs.

6 Conclusion

This paper presents an ergonomic posture assessment tool which utilizes the depth sensing techniques of a 3D imaging sensor to conduct an ergonomic risk assessment of seated worker's postures during controlled manual handling tasks. The tool consists of the Microsoft Kinect sensor and its data-retrieval software application on which the H&S recommendations for manual handling activities were incorporated.

When tested on some selected seated Operators, the tool was found to measure and assess the postures of the upper bodies of the Operators with real-time feedback to the seated workers to alert them on when to adjust awkward postures which may be detrimental to their health when held for prolonged period.

Finally, the developed tool is beneficial to every workplace that seek to improve worker's productivity and plant efficiency as it can help to reduce the rate of occurrence of awkward postures among its seated workforce.

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Three Times Smart – Smart Workplaces, Smart Lighting & Smart Glass

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Abstract. In the future workplaces, the new technology devices will be present at all times, so new spaces will need a new approach to lighting design, and in order to achieve this it will be necessary that the lighting systems, and the workplaces get smarter. New technology turns the present-day workplaces less efficient. In lighting, there are new luminaires that help us to manage our physiological and psychological needs. Besides, there is also smart glasses which are a very recent innovation that can help us to take advantage from the positive form of the sun, the promotion of vitamin D production. To achieve such goals the research will be conducted throughout literature review. We expect to conclude that LED is the most efficient lighting system but we suspect that it is not any kind of LED system that will respond, and manage, our circadian, as well as, our visual needs.

Keywords: Visual and non-visual · LED · Workplace · Glass · Wellbeing

1 Introduction

With so many evolutions in so many knowledge fields, as well as in technological systems we need to adjust to them at a rate that may not be very positive. In order to cross the information of some of the main technologies that can help us to cope with this transition into the future we will begin to explain how can we improve and maintain our health and wellbeing at workplaces. Visual and Nonvisual systems are influenced by external cues, and we will discuss some of them. Afterwards, we will start with the new achievements in lighting systems, the recent technologies and how they can help us to improve health and wellbeing. LEDs are the lighting system that can avoid mercury presence in fluorescent light system, can promote our nonvisual systems through the blue light and are more efficient. We will draw our attention to differences between its ancestors on lighting systems (incandescent, halogen and fluorescent) but our focus will be LEDs. Then, we will talk about technologic evolution that is being held at workplaces. Lastly, we will state the recent approaches to glass, specifically the smart glass devices.

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2 Literature Review

2.1 Visual and Nonvisual Systems

The visual system depends greatly on light in order to enables us to see but so does the nonvisual system. Daylight enables us through the eyes (visual) to reset and synchronize our circadian rhythms (nonvisual). Visually speaking, the human eye is more sensitive to green light (550 nm) and this sensitivity decreases towards the red and blue ends of the spectrum [2]. In addition, it is on the blue end of the spectrum that the production of melatonin is stopped, whereas the red end promotes its production. So, the colour of light is not irrelevant for our nonvisual functions. Nonvisual, through the circadian rhythms, regulates important physiological and behavioural rhythms, such as sleep-wake cycles, alertness and performance patterns, psychomotor vigilance, cognitive brain functions, attention, memory, CBT (core body temperature), heart rate, and hormone production. Besides melatonin (darkness hormone), serotonin (mood hormone) and cortisol (stress hormone) also depends of light. However, serotonin and cortisol are influenced by the intensity of light, when the light is brighter (blue light) these hormones are produced. The downside is how to achieve the equilibrium, if we stay under bright light exposure too much time cortisol, for instance, will give place to adrenalin and noradrenalin production which are not so good for stress levels, since it exposure can lead to heart problems in the future. Without light, we will not only stop being able to see, but also our mood will decrease greatly, SAD (seasonal affective disorder) is a result of insufficient levels of light exposure, which occurs mainly in the winter months due to sunlight weakness. When we believed that light only helped us to see it was easier to conceive indoor places, such as workplaces. But, at the present time, we know that nonvisual functions also depend on the brightness and wavelength of ambient light [1, 2].

So, the visual functions are driven by two types of visual photoreceptors in the retina, cones and rods. Rods (scotopic) have a peak of sensitivity at 505 nm, while the cone's peak sensitivity (photopic) happens at 555 nm (Fig. 1). On the other hand, nonvisual functions are mediated through a photoreceptor that contains the photopigment melanopsin, the ipRGCs (intrinsically photopigment retinal ganglion cell). IpRGCs are circa 2% of the retina, situated outside the fovea. Melanopsin is more sensitive to short-wavelength light at 480 nm (blue light). The sensibility of ipRGCs varies in the intensity, duration/pattern, and timing of light exposure when compared to vision. Surprisingly, there is a cooperation between the photoreceptors and ipRGCs, for example, cones, combined with ipRGCs, contribute to non-visual responses at the beginning of a light exposure and at low irradiance, although they are slower and lazier than cones and rods [3]. Even though, at long exposures to high irradiances is the ipRGCs that take over. In the course to continuous light exposure, ipRGCs the contribution [4]. Another fact is that, due to its sluggish, ipRGCs do not respond to individual intermittent light exposures of low irradiance [4].

To sum up, we can say that it is the short-wavelength portion of the spectrum (446–477 nm), the blue light, that results into melatonin suppression from the pineal gland and, at the same time, enhances alertness, increases heart rate and body temperature and induces expression of the circadian click gene Per2 in humans, whereas

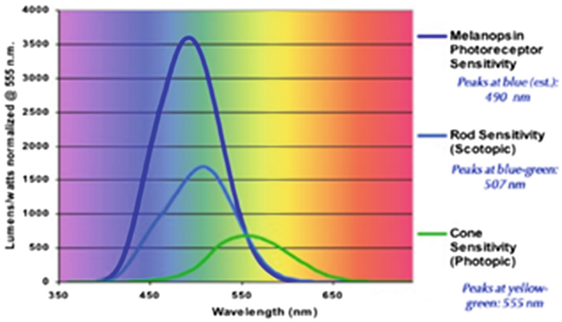

Fig. 1. Cones, rods and ipRGCs sensitivities [5].

long-wavelength exposure is three times less powerful. We are giving special attention to blue light side effects, positive and negative, just because the ultimate light technology works under its spectrum, such as the case of LEDs. We, also, stated that intensity of light, spectrum, timing, duration and spatial distribution are light factors that have to be considered in order to allow us to achieve a balance between the visual and nonvisual systems [6].

2.2 LEDs

Light-Emitting Diodes (LEDs) are entering through our workplaces, and homes mostly due to economic reasons, since they are more durable, compact, and versatile and only consume one-tenth of the power that is used to consume by incandescent lighting. On the other hand, extensive biomedical research showed that LED can have influence on our biological and behavioural systems. Furthermore, LEDs can be controlled for changes on the light five characteristics (intensity, spectrum, timing, duration, and distribution) and thus be a help to our circadian, neuroendocrine and neurobehavioral physiology, at least it is already used for doing so with astronauts. In opposition, short-wavelength light (blue light) can be helpful for disrupted sleep, circadian rhythms synchronization or diminished alertness due to the fact that blue light increase melatonin suppression [6].

Another important fact, is that we are more familiarized with incandescent and fluorescent artificial lighting systems. But, the truth is that the first one was already discontinued and the second is the next one. Therefore, we will discuss the new lighting system that, if we give the right attention to it, we will perceive that these kind of technology are different. The old lighting systems (incandescent, halogen, and fluorescent) and the new ones (LED) are based on different technologies, the first ones are electrical and LEDs are electronic. So, if we think about the measurements, they are not the same. Until now, when we think of a lamp we think of watts, but now, when we want to buy a lamp there is another unit, the lumen. As a result, we think lamps for their wattage output, and then we tend to do the same with LEDs. However, a standard 60-watt incandescent lamp emits 800 lumens, but the light is emitted equally in all directions. Then again, lumen is a standard unit that measures the perceived power of a light source. Lumen is not the best way of measuring a LED light source but delivered light (illuminance) is. Illuminance is the intensity of light falling on a surface area and if it is measured in square feet, the unit is foot-candles (fc), and if it is measured in square meters, the unit is lux (lx). For example, 50 fc are equal to 500 lx [7]. LEDs are directional and create light without filtering or additional lensing and shading. The result is that other lighting systems, such as fluorescent, waste more light which can be partially blocked or dispersed, as well as emitted towards other direction than the one that is supposed to, or simply the light can be list through filtering or lensing features. Therefore, a LED lamp deliver more light and with a higher lumen output and this makes the LED much more efficient [7]. Plus, the LED cost will continue to decrease and savings will increase [8]. Again, this is an important information since we are used to think in watt unit, and we neglect the part that different technologies have different unit measures and the light itself have other characteristics (the light beam of a LED is more accurate than a light beam of the older technologies, so we should not compare them if we do not have this in mind).

Another fact is that conventional lighting fixtures are tested using the relative photometry method, where lamps and luminaires are tested separately. So, the lumen output of a fixture´s lamp is a reference and the lumen output is a percentage of total lamp lumens, which in turn is the efficiency of the luminaire [7]. Then again, LEDs are inseparable from the luminaires, so LED are tested using absolute photometry. But then again, in absolute photometry lamp lumens are not measured, just fixture lumena are.

In addition, there is another difference between LED and older lighting systems, since CRI (Colour Rendering Index) is not the best for measuring the ability of a light corresponds to the real colour. For example, natural light have an IRC of 100, whereas a CFL (compact fluorescent light) have an IRC between 50 and 70 and many LEDs have 90+. Colour Quality Scale (CQS) (CIE TC1-69) involves aspects of colour like colour rendering and chromatic discrimination. The major differences between CQS (Fig. 2) and CRI are that the first takes into account subjective colour saturation perception, measures colour fidelity according to colour saturation preferences, and like CRI identifies the colour with a number [9]. Nonetheless, many LEDs have very little red content, some have a negative R9 value (CRI is based on R1–R8. R9 is one of 6 saturated colours not used in calculating CRI.) [8].

Fig. 2. Colour Quality Scale (CQS) (CIE TC1-69) [9].

As we can see in the Fig. 3, LEDs have a peak wavelength in the blue light range and this is another huge difference between the older lighting systems (Figs. 3 and 4). Moreover, blue light is the dangerous part of the visible spectrum, since it generates ROS (reactive oxygen species) in the retina. ROS like lipofuscin (the age pigment, which starts to build up in childhood) accumulates over the years [10]. ROS has been linked in the pathogenesis of retinal degenerative diseases such as AMD (age-related macular degeneration), and can cause photochemical damage, leading to the death by apoptosis first of RPE (retinal pigmental epithelial) cells and afterwards of photoreceptors [11]. RPE cells are the photoreceptors suppliers of nutrients and thus, vital to the renewal of visual pigments and promotes the functioning of photoreceptors. So, blue light damages RPE which are our allies against lipofuscin, and ROS. And, these facts, are of extreme importance when we are working with elderly people, since the laboral laws are changing and we will have people with more than 65 years old working. We must be aware that as the eye ages, light transmission and absorption also change, because of the yellowing of the crystalline lens and repair mechanisms will be less operational [11]. Besides, pupil size also decreases and will disrupt the photo-entrainment of circadian rhythm, since less light enters in the eye. It is important to retain that blue light constricts pupil, increasing visual acuity. Conversely, LEDs do not emit ultraviolet (UV), which can cause sunburn (skin) or have effects in a cellular/DNA level, or infrared (IR) radiation, that can promote discomfort due to the heat that it creates. And, yes, we already seen that blue light is important for our nonvisual system [12]. However, even though the eye have natural mechanisms of defence, we have also seen that they are less effective during the time.

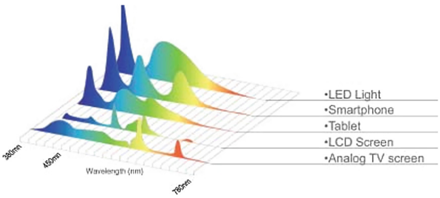

Fig. 3. Spectral spectrum of LEDs [13].

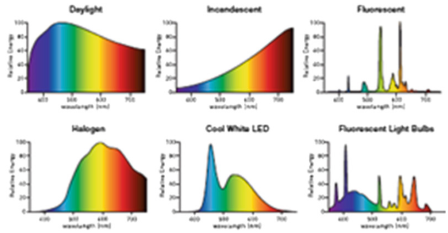

Fig. 4. Spectral distribution of different light sources [11].

The IESNA (Illuminating Engineering Society of North America) in Recommended Practice 27 [10] classify light sources according to their level of radiation risk. It consists in four classes, from 0 to 3 exempt (risk groups). Exempt group O (RG0) is the one where light sources do not pose a photobiological hazard for 10,000 s (about 2.8 h). Whereas RG1 (Risk Group 1 or Low Risk) is that light sources in this group exceed the limits of RG0, but do not pose a hazard due to normal behavioural limitations on exposure, with maximum exposure times are between 100 and 10.000 s. While, RG2 (Moderate Risk) is that where light sources are longer than RG1, but do not pose a hazard due to the aversive response to very bright light or to thermal discomfort, between 0.25 and 100 s. Any light source in Risk Group 3 (High Risk) is believed to pose a hazard, even for momentary exposures, less than 0.25 s (Table 1) [12].

To sum up, we must have in mind the differences and the concepts stated above when choosing a LED, since it will be the lighting system of the future and for this reason it is, somewhat, considered the smart lighting system. However, this smartness is due to other factor, such as that LED chips can dim, but not all LED fixtures. Even though, LEDs can be more efficient when they dim because the run cooler when

Table 1. Overview of the risk groups according to IEC 62471 and of the data of relevance to LEDs, including the applicable emission limits. [Adapted from 14]

Risk group	Safety message	Exposure periods to determinate (emission limits)	
		Retinal photochemical hazard	Retinal thermal hazard
Group 0 - Exempt	No photobiological hazard	10,000 s	10 s
Group 1 - Low Risk	No hazard due to normal behavioural limitations on exposure	100 s	10 s
Group 2 - Moderate Risk	No hazard due to the aversion response to very bright light sources or due to thermal discomfort	0.25 s	0.25 s
Group 3 - High Risk	Hazardous even for momentary exposure	<0.25 s	<0.25 s

dimmed. Flicker, nonetheless, can be a downside of LEDs because some LEDs drivers have visible and nonvisible flicker. There are two kinds of flicker, visual and nonvisual, but the last one can be sensed. The negative side effects of both can cause headaches, eyestrain and even seizures. However, dimming LED systems can have little or no flicker when dimming. The answer may turn out to be using sensors on the exterior, controls and occupancy sensors in order to automatically adjust light levels, CCT and colour, dependent on the task that is undertaken [8]. LEDs with tuneable Kelvin and intensity can be the right answer (Fig. 5). However, there are many issues that we have not got the best answer as we already stated.

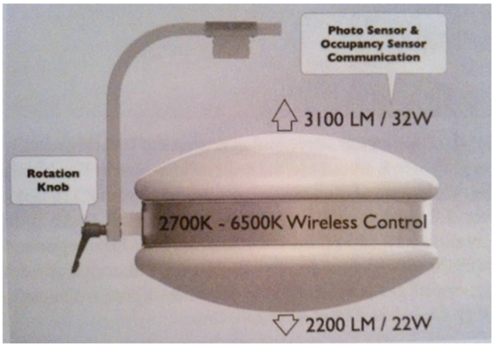

Fig. 5. LED with tuneable Kelvin and intensity [8].

2.3 Workplace

Nowadays, workspaces are changing faster, and even though there are many open-space offices, the technological revolution that stimulates evolution [14]. Smart

Work is a new way of working due to advances in technology. These changes will influence the way we work. There are several benefits from smart working, such as creating office atmospheres that promotes collaboration and innovation, or by reducing environmental footprint. In order to achieve that we need to implement flexible working options, technologies that support flexible working, reduce physical meetings and use repeatedly virtual contact. It is necessary to start implementing a more modernized working practice, which empower employees with the possibility of choosing where and when they work, and therefore they will have a more balanced work-personal life, and will be healthier and consequently more productive. It is not just a matter of doing the same with new technologies but creating new ways and approaches. We have to step aside from the Taylorism approach to the workplace, just because the focus must be on the people and not, only, on the costs [14].

And for that we have to achieve different environments, more flexible and less rigid. For example, provide different lighting systems from the ones that are used actually, not a static light but a dynamic one. The use of task light could improve the employee's 'wellbeing since each one could adjust the light to their needs, preferences, according with the task performed. Besides, with age we need more light as well as the people that have some kind of visual impairment and the ones that are younger and with a perfect visual acuity [8]. For instance, a light with 8200 K is the best option for elderly, since they feel less fatigued. Moreover, visual functions are worse - like visual acuity and accommodation - and pathologies such as cataracts begin to appear, besides the lens yellowing that degrades the colour's distinction. On the other hand, the most suitable correlated colour temperature (CCT) for young people is 2500 K, as we can see it is a huge gap between them. Thus, it seems that 5000 K, a value between 8200 K and 2500 K, is a CTT that can be considered pleasant for both. So, we can stabilise a medium CCT in order to respond to all ages, however, as we stated it may not be the best one. Today, we live in a society that has a role-model of "one size fits all", but the truth is that it can fits all but only in a medium way. If we know that our needs are different why do we insist that we have all to be alike? We are different, social, economic and culturally, just to name a few, so why do we keep to say that we are all equal? To make us get along and accept our differences is one thing, to see us all by the same ruler is another thing. So, besides the stated above, we must not forget, other issues like how to avoid glare sources. This is another concern because adjusting light, is not just a question of preference, a health related issue or an age concern. Lighting systems, at workplaces, are usually located in the ceiling and many times are controlled by one person for all the building, or for all the floor. But as we have already seen, there is too much questions that we have to answer, so the best way to answer it can be, simply, allow people to decide if they want to, or need to, move the lamp or re-direct it. Another curiosity is that the computers have a screen that is auto-illuminated so we do not need more light to see it, because it is already lighted. In fact, less light is better than more light. Flexibility is the right word [8].

The accelerating pace of our modern life turns into something that if we do not evolve along will, eventually, play against us. Technology surpasses us really fast and we must stop to think how can we take benefit from it. And this benefit is not based on costs; it should be in the promotion of users' health and wellbeing. Since technology removes obstacles we should not make, create or continue to suffer their consequences.

One example of this can be the poor postures that increases the risk of musculoskeletal disorders and carpal tunnel syndrome as a consequence of the new technologies. When we seat on an ergonomic chair and look over a pc monitor our eye should look straight forward and our posture should be aligned, but when we look to a tablet or smartphone our posture is misaligned, which will lead to pain and will do long-term harm to our bodies [14].

So, besides lighting needs, wellbeing in a more general way, is also a challenge for the most recent workspaces. Stress plays an important role, but as we had already stated, can happen due to lighting characteristics too. The empowerment of the employees in order to permit that they can control their environmental cues individually can turn out to be a headache. In an open space, it is almost impossible to do so. Thus, the spaces and its compartmentation have to change inevitably. In spite of the fact that employees may not have the right knowledge of certain areas that gives them the information that can, directly and indirectly, help them to achieve health and wellbeing. They might be misinformed.

2.4 Wellbeing

As regards wellbeing, besides the facts that have already been discussed and state there is also the fact that people have been dependent and evolved under the natural light, sunlight, and Earth's natural cycle (latitude, longitude and seasonal [8]. In the morning, the light is very different from the light at midday. Low light level and a warm CCT are the characteristics of the morning and of the late afternoon, while at the midday is the opposite, a high light level and a cool CCT [8]. Once again, the natural light is dynamic and our timings (circadian rhythms) are related to its timing. We are spending too much time of our lives inside buildings of some sort whereas until not so long ago we were attuned to outside environment. Artificial light is very different from the natural one and its impact on our visual and nonvisual systems is questionable.

2.5 Smart Glass

Research over the last decade leads to the development of new and adaptive materials, and glass in no exception. Smart windows are smart devices that are able to respond to variations in temperature, solar radiation and might reduce the energy consumption and increase comfort at indoor environment, such as workplaces [15].

Windows can increase the energy consumption and heat gain. Smart glass could be an excellent way of improving energy consumption as well as adjust the glass characteristics to our needs. For example, we can turn the glass less clear and increase privacy when required. There are several types of smart glasses (Fig. 6), such as liquid crystal (LC), low-emissivity (low-E), thermochromics, electro comic and SPD (suspended particle devices). Besides, liquid crystal, electrochromic and SPD are all electrically activated and are the different devices of electro tropic [15]. For a better understanding, let us discuss the concept and the main advantages and disadvantages of each type (liquid crystal (LC), low-emissivity (low-E), thermochromics, electro comic and SPD).

Fig. 6. Some types of smart glass [16].

Firstly, liquid crystal glass is made up of two sheets of glass with a liquid crystal film between them. When the electric field is applied the orientation of LC chains are altered and the optical transmission of the glass too. And, without electric field the molecules are scattered and visual light is diffused, which gives the translucent effect. The main advantage is that we can adjust its opacity however, the down side is that it does not conserve energy (Fig. 7).

Whereas the advantages of Low-E glass is that it limits ultraviolet light from getting in, which in turn will protect the furniture from fading, reduce sound levels indoors and decrease the energy costs. As for disadvantage it is more expensive than regular glass and no control over the visible light (Fig. 8).

Thirdly, thermochromics glass continuously adapts its tint to sunlight and in that way, manages the heat and glare without power supply. Even though, it cannot be manually controlled due to the fact that is a passive technology, which responds to environmental changes in temperature, and may not receive from sunlight the right amount in order to darken (Fig. 9).

Fourthly, electrochromic glass is dependent on electrical current for changing its colour state. Among the its benefits is the possibility to include sensor to automatically tint the glass, this control of each window can be through manual control, in this way we can have more natural light without interrupting views which will increase comfort and productivity (Fig. 10) [15, 16].

Lastly, SPD is a type of glass based on a film technology and have a uniform response all over the film. When no electrical charge is applied the particles are in random positions and block light transmission while turning in a dark blue tint. Whereas with charge the particles align and let the light get through. When the switch is on, the glass turns clear, allowing 45% visible light transmission. When there is no

Fig. 7. Liquid crystal glass [16].

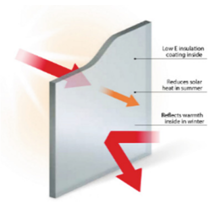

Fig. 8. Low-emissivity glass [16].

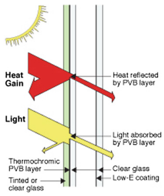

Fig. 9. Thermochromics glass [16].

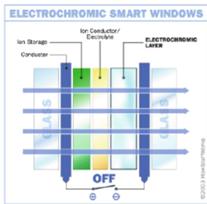

Fig. 10. Electro comic glass [16].

current the glass is blue tint and allows less than 1% of visible light transmission. Besides, in all states it rejects 99% of ultraviolet light transmission. Advantages of SPD: optical view through the window, even with bluish tint is possible to see through the glass, and a comfortable room temperature can be maintained thus preventing unwanted fluctuation linked with the change of external temperature [15].

From the Fig. 11, we can see that SPD have the best performance in reducing visible light transmission, thermotropic at higher temperatures have the top performance.

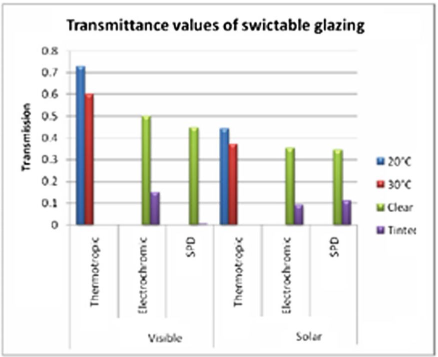

Fig. 11. **Comparison** of visible and solar transmittance values between switchable glazing devices [Adapted from 15].

3 Discussion

Flexibility seems to be a better word than smart. We will explain this for each technology/concept in this paper discussed. Actually, we do not need a smart light we need a dynamic one, which is more similar to natural light since it is by sunlight that we evolved as a specie. So, we need a lighting systems that provides a wider range of CCT, light intensities (Lux, watt, lumen), lighting systems layout (where is the light/lamp? What is its orientation, towards a paper – horizontal – a computer screen – vertical?). These are all questions about light, there is not a god or a bad answer, it all as to do with the case to solve: where is the building located? Does it have east and west light? Besides, an endless variables, the light itself, the artificial light, must answering to many issues, and it seems that a light which varies all over the day with an "automatic" adjustment can be the better choice, once this is the most flexible solution. Permit to users a control over their workstations can be a helpful way of give them the autonomy over their comfort and wellbeing. As for, a smart workplace, well a smart workplace besides the technology, nowadays, it is an old concept. The majority of individuals work in computers, which are presenting smaller and smaller dimensions. So, we do not have to be seated at a desk all day long. We can work in a patio, or somewhere else, we just have to be wired to Wi-Fi and have a computer, a smartphone, or a tablet. And, if it is so, why do we must kept in one room with the same persons all day long? We may need some silence around us in order to keep us concentrated on the undertaken tasks. Or we are very sociable persons and need to have people around us to achieve the same purposes (to be concentrated). We may appreciate to have a natural place near or we may prefer the rush of a city traffic and its related characteristics sounds. Technology is offering us the freedom of choice, we can work (almost from) anywhere. Well, honestly, we should not work everywhere and in every way but at least we can move around, choose different ambiences, desks, seats, lights, people around. Once again, flexibility is the right word. Lastly, smart windows, are they smart? Yes, they are if we think of energy consumption, privacy issues (tinting the glass, or unclear it). But, what was identified as a one of the major health problems nowadays, around the globe? The lack of vitamin D is, for sure, one that have been underestimated and the majority of this smart glasses simply limit the ultraviolet light indoors, and by doing so, the UVB light does not enter inside precisely when the people should be exposed to it (from 11 a.m. to 4 p.m.). So, we are protecting the surfaces and furniture from fading from ultraviolet but we are putting us in danger. And, what is more important? The furniture or individuals? Once more, this is a recent technology, and we must to turn it into a more flexible one: we can limit the ultraviolet radiation from getting in, but at the same time, we should allow it for some time during the day, forty minutes during the summer is enough, for instance. For this technology being considered smart we must (and all of the types of glass here stated are taking the first steps) turn them more flexible and architects and designers ought to be more informed about health, sustainability and management related issues. Despite our academic level and professional competencies, we must, and we need, to get smarter.

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Analysis of Infrared Imaging During Vertical Handling Tasks in Workers with Different Levels of Obesity

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Abstract. Obesity is an emerging health problem and its incidence has been increasing throughout the workforce. In occupational contexts, the vertical handling tasks, including lifting and lowering loads, are common and can produce significant musculoskeletal overloads for the involved workers. In this field, the Infrared Thermography (IRT) has emerged as a potential technique to analyze risk factors for Work related Musculoskeletal Disorders (WMSD). Thus, this study aims at comparing the surface temperature changes over 16 Regions of Interest (ROI) across a sample of individuals with different levels of obesity, when performing a vertical handling task. The results pointed out that, for all considered ROI, the skin temperature decreases after the task and obese subjects seems to present a higher decrease, comparing with the non-obese. Negative temperature variations may present a higher risk of WMSD due to blood flow restriction. This study provides evidences that obesity is a WMSD risk factor during handling tasks.

Keywords: Obesity · Vertical handling tasks · WMSD · Thermography · ROI

1 Introduction

Obesity is currently referred to as a 21st century epidemic public health problem, affecting both developed and developing countries. Over the years, European countries, including Portugal, have been following the global tendency of overweight and obesity increasing. In the last two decades, the World Health Organization (WHO) estimated that obesity has increased three times [1]. In Portugal, statistical data demonstrates that the people with unhealthy weight are more than 50% of all population [2]. Obviously, obese people represent a significant fraction of the global working population [3]. However, several studies have demonstrated that obesity can cause limitations, both in daily life and in the individual's work activity. For example, workers with overweight are absent from work due to illness more frequently and for long periods than employees with normal weight [4], being this absenteeism frequently related to WMSD [5].

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In the occupational context, obesity is an individual factor that may compromise the work ability, for example through changes in the individual's postural balance [6]. This evidence gains more emphasis through results that point out that obese workers report a higher perceived overload during tasks of holding loads at different postures [7]. However, the effect of obesity in postural work maintenance is a condition that is rarely studied. Furthermore, in ergonomic interventions at workplaces, the postural analysis tools seem to consider only workers with a normal weight.

It should be noted that one of the disorders caused by stressful postures is back pain. From the biomechanical point of view, excessive body weight can negatively affect the muscles and spine behavior during handling tasks. Different studies have found positive relations between obesity and back pain [8], as well as the decrease in the trunk muscle strength [9]. However, the epidemiologic literature research has not clearly demonstrated the link between low back pain and obesity [10].

In this context, several findings have shown that workers who perform manual handling loads are exposed to a greater risk of having back pain and WMSD, compared with those that their jobs do not require this type of tasks [11]. This type of tasks, including lifting and lowering (in this paper designated as vertical handling tasks), is very frequent in the occupational contexts and are associated with the WMSD appearance in the workers who develop them [12], which justifies the choice of these tasks as object of study in the current investigation.

This type of tasks involves several muscle groups that contract and relax, during dynamic work performance. This whole process involves different physiological processes to which heat release is associated. Heat transfer, in the objects, as in the human body, can occur by 3 main ways: conduction, convection and radiation [13]. IRT captures the natural radiation emitted by a body surface, but it has to present a temperature above zero [14]. For this, the infrared cameras have heat detection capability, based on the sensitivity to the electromagnetic waves emitted by the human body, which reflect the molecular agitation of the tissues [14]. The high-resolution images captured expose the skin temperature, using a quantitative color scale. This skin temperature depends on the combination of blood flow, energy expenditure and nutrient metabolism, and can provide important data about physiological function of the tissues [15].

It is important to mention that IRT is a non-invasive and non-ionizing technique, being innocuous for those who participate in the study [14]. In the last years, IRT has been widely used for clinical purposes, namely in the diagnosis of musculoskeletal disorders, oncology, vascular disorders, arthritis, sports medicine, among others [15].

This technique has also been applied as a valid option in WMSD risk factors assessment. Different exploratory studies have shown that variations in skin temperature are related to physiological responses to specific conditions of occupational tasks. These evidences were found in tasks with static exertions (overhead tapping tasks) [16, 17] and repetitive muscular work (typing task in work office) [18, 19], essentially for the body regions of hands, shoulders and forearms.

In summary, obesity can affect individual work ability, including performance during vertical handling tasks. Although obesity has already been widely studied, there are some controversies associated with this individual factor, and further studies are needed. In addition, it should be noted that IRT is a direct measurement technique applicable to WMSD risk factors assessment. Therefore, the objective of the current work is to perform an exploratory study to assess and analyze surface temperature chances in individuals with different obesity levels, during vertical handling tasks.

2 Methodology

2.1 Participants and Experimental Task

Twenty-nine participants (10 females and 19 males) without symptoms and no previous record of musculoskeletal disorders were recruited. After signing an informed consent form, different individuals' anthropometric data were quantified, such as Body Mass Index (BMI) and Waist Circumference (WC). Additionally, an OMRON® BF306 body fat monitor was used to measure the Body Fat Mass (BFM) percentage, determined by bioelectrical impedance, which also integrates personal data (height, weight, age and gender), in order to accurately define individual obesity levels [20]. Mean and Standard Deviation (SD) of the personal data are presented in Table 1.

Table 1. Mean and SD of age, BMI, WC and BFM (n = 29).

Personal data	Mean	SD
Age (years)	33.4	9.7
BMI (kg/m^2)	25.1	4.6
WC (cm)	89.4	14.0
BFM (%)	26.0	8.7

Considering the BMI, the participants can be distributed across 3 obesity levels [1], namely: (i) normal (n = 18); (ii) overweight (n = 7); and (iii) obese (n = 4). The WC measures the abdominal fat and has been used to predict the risk of cardiovascular disease related to obesity [2]. Considering participants' WC and gender, different levels of risk of disease can be defined, such as: (i) normal (n = 16); (ii) high risk (n = 5); and (iii) very high risk (n = 8). Relatively to the BFM percentage, the body fat monitor defined the following obesity levels: (i) normal or non-obese (n = 10); (ii) high (n = 13); and (iii) very high (n = 6). All participants were instructed to avoid drink, eat and smoke at least 2 h before the test.

In a laboratorial context, each participant performed a repeated and symmetrical task of lifting, and replacing, a box with a load of 7 kg, between floor and shoulders height. The periodicity of the repetitions was 7 s, during 2 min. The task was performed in a postural constrained condition, likewise the box was placed behind a 60 cm high barrier simulating one side of an industrial bin. The high barrier was constructed to measure 120% of average male and female knee heights [21]. This experimental design took into account the guidelines published by the National Institute Occupational Safety and Health (NIOSH) [22].

2.2 Thermographic Data Collection and Analysis

The participants acclimated themselves to the laboratory climatic conditions (mean relative humidity 58.2 ± 1.7%, mean temperature 23.3 ± 1.2 °C, no direct ventilation and fluorescent lighting over the subject) during 15 min, without clothing, accessories and hair over the body regions of neck, arms and upper trunk [23].

Before and after the vertical handling task performance, thermal images from anterior and dorsal corporal views were collected, including the body regions mentioned above. During the measurements each participant were stand up and set 3 m from the infrared camera in an uniform background. The infrared camera used in this study was a FLIR® E60sc, with a sensor array size of 320 × 240, NETD of 50 mK at 30 °C and traceability of ±2% of the overall temperature range reading (Fig. 1). The emissivity value was set to 0.98, considering the value of human skin emissivity suggested by the most of researchers who apply IRT [24, 25].

Fig. 1. Infrared camera FLIR® E60sc (Courtesy of FLIR company).

The software used to load and process the thermal images was the FLIR ThermaCam Researcher Pro 2.10®. In this study, 16 ROI were studied (Table 2 and Fig. 2), being their definition made according to the Glamorgan protocol [26] and the software quantified the skin mean temperature for each ROI. The ROI selection was supported

Table 2. Description of the 16 ROI considered in this study.

	ROI	Description		ROI	Description
Anterior	01	Right shoulder joint	Posterior	01	Left shoulder joint
	02	Left shoulder joint		02	Right shoulder joint
	03	Upper ligaments of right shoulder		03	Half of the left neck
	04	Upper ligaments of left shoulder		04	Half of the right neck
	05	Lower ligaments of right shoulder		05	Left trapezius
	06	Lower ligaments of left shoulder		06	Right trapezius
	07	Right arm		07	Left arm
	08	Left arm		08	Right arm

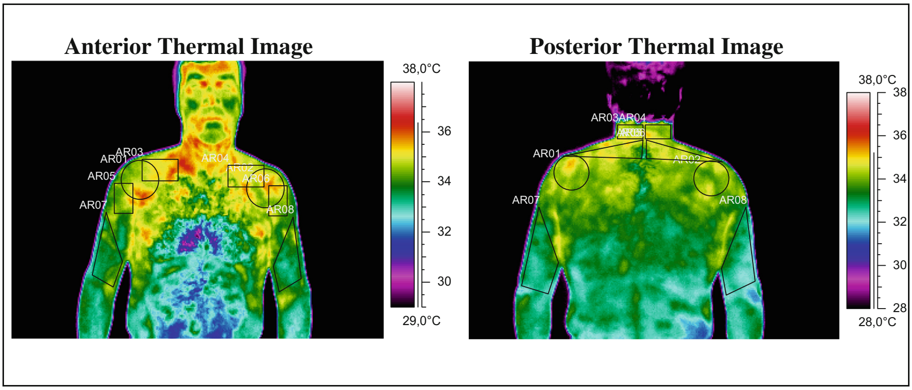

Fig. 2. Examples of thermal images for anterior and posterior views with the 16 ROI defined.

by the functionality of muscles and articulations, located in these regions, during this type of tasks. In addition, it was observed that fat mass accumulation was not high in these body regions, which, had it been, might have compromised thermographic data acquisition.

Considering that the BFM is a factor which can influence the skin mean temperatures [25] and the participants presented different levels of obesity, the analysis of the thermographic results was made from the delta of temperatures (ΔT) calculating. For each ROI, ΔT was determined by the algebraic difference between the skin mean temperature measure after the task performance minus the basal temperature (measured before the task), as suggested by Formenti *et al.* [27]. The values for this variable could be either positive or negative depending whether skin mean temperature increased or decreased during the vertical handling task.

Relatively to statistical analysis, it was performed using the IBM® SPSS® Statistics 24.0 software. The ΔT data were presented as mean and SD corresponding. The normality of the distribution of the personal data and skin mean temperatures was checked by the Shapiro-Wilk's test. All the parameters did meet the assumption of normality. For this reason, a Pearson test was applied in order to check if the ΔT increase/decrease is correlated with the individuals' obesity level increase (measured by BMI, WC and BFM percentage).

3 Results and Conclusions

Concerning ΔT values, a descriptive statistical summary of these values across the 16 ROI and the different obesity levels (defined by IMC, WC and BFM) is provided in Table 3. The ΔT mean values are negative for all ROI considered, indicating a cooling of the surface areas, potentially a result of the vertical handling task performance. These results pointed out that skin temperature decrease after the task. This evidence showed that IRT are sensitive to identify skin temperature differences caused by vertical handling tasks

Table 3. ΔT mean and SD values for the 16 ROI across the different obesity levels, measured by BMI, WC and BFM.

ΔT mean ± SD (°C)										
	ROI	BMI			WC			BFM		
		Normal	Overweight	Obese	Normal	High risk	Very high risk	Normal	High	Very High
Anterior	01	−0.28 (0.55)	−0.37 (0.60)	−0.70 (0.72)	−0.29 (0.59)	−0.06 (0.17)	−0.69 (0.63)	−0.27 (0.65)	−0.28 (0.43)	−0.68 (0.73)
	02	−0.25 (0.67)	−0.21 (0.43)	−0.65 (0.58)	−0.26 (0.71)	−0.02 (0.28)	−0.54 (0.48)	−0.25 (0.77)	−0.25 (0.52)	−0.48 (0.52)
	03	−0.31 (0.52)	−0.19 (0.40)	−0.55 (0.72)	−0.31 (0.57)	−0.08 (0.23)	−0.46 (0.54)	−0.29 (0.62)	−0.28 (0.42)	−0.43 (0.60)
	04	−0.29 (0.57)	−0.17 (0.39)	−0.62 (0.62)	−0.31 (0.60)	−0.02 (0.33)	−0.50 (0.47)	−0.33 (0.66)	−0.21 (0.44)	−0.48 (0.53)
	05	−0.25 (0.52)	−0.34 (0.50)	−0.80 (0.62)	−0.26 (0.56)	−0.08 (0.24)	−0.70 (0.51)	−0.25 (0.63)	−0.28 (0.45)	−0.65 (0.57)
	06	−0.26 (0.64)	−0.33 (0.50)	−0.67 (0.62)	−0.31 (0.66)	0.02 (0.33)	−0.61 (0.52)	−0.29 (0.75)	−0.26 (0.52)	−0.57 (0.53)
	07	−0.29 (0.64)	−0.39 (0.38)	−0.60 (0.57)	−0.31 (0.68)	−0.16 (0.33)	−0.57 (0.44)	−0.32 (0.79)	−0.31 (0.44)	−0.52 (0.46)
	08	0.17 (0.70)	−0.36 (0.42)	−0.67 (0.51)	−0.20 (0.73)	−0.02 (0.31)	−0.62 (0.42)	−0.29 (0.84)	−0.16 (0.50)	−0.55 (0.44)
Posterior	01	−0.43 (0.35)	−0.67 (0.41)	−0.97 (0.76)	−0.47 (0.35)	−0.44 (0.46)	−0.82 (0.60)	−0.39 (0.37)	−0.60 (0.40)	−0.77 (0.67)
	02	−0.54 (0.35)	−0.61 (0.39)	−0.92 (0.75)	−0.56 (0.37)	−0.58 (0.31)	−0.75 (0.60)	−0.51 (0.41)	−0.64 (0.31)	−0.73 (0.66)
	03	−0.44 (0.38)	−0.53 (0.42)	−0.77 (0.66)	−0.44 (0.39)	−0.54 (0.40)	−0.62 (0.55)	−0.34 (0.39)	−0.61 (0.36)	−0.57 (0.60)
	04	−0.40 (0.36)	−0.56 (0.41)	−0.70 (0.69)	−0.42 (0.37)	−0.38 (0.33)	−0.66 (0.56)	−0.35 (0.35)	−0.54 (0.40)	−0.57 (0.59)
	05	−0.42 (0.30)	−0.52 (0.37)	−0.82 (0.62)	−0.43 (0.30)	−0.38 (0.27)	−0.71 (0.53)	−0.38 (0.30)	−0.52 (0.35)	−0.65 (0.55)
	06	−0.49 (0.30)	−0.56 (0.28)	−0.85 (0.73)	−0.49 (0.30)	−0.48 (0.23)	−0.72 (0.55)	−0.45 (0.32)	−0.57 (0.28)	−0.70 (0.62)
	07	−0.38 (0.24)	−0.40 (0.26)	−0.45 (0.25)	−0.43 (0.21)	−0.28 (0.26)	−0.40 (0.28)	−0.40 (0.25)	−0.42 (0.23)	−0.33 (0.27)
	08	−0.35 (0.28)	−0.49 (0.33)	−0.57 (0.35)	−0.39 (0.27)	−0.30 (0.23)	−0.52 (0.38)	−0.32 (0.33)	−0.47 (0.25)	−0.45 (0.36)

performance, providing a preliminary demonstration that IRT may be useful in quantifying work tasks demands (as supported by Barker *et al.* [16]).

Furthermore, comparing the ΔT mean values between groups with different obesity levels, the results suggest that there is a tendency to increase skin cooling for the participants with higher obesity levels.

A decrease in skin temperature during and at the end of an exercise, as reported by the current results, was previously observed by some studies [16, 27–29]. Regarding the reason of that skin cooling, this is associated with changes in blood flow. A study in this field [30] demonstrated that during continuous muscle contractions performance with moderate intensity, as with the repetition of lifting and lowering a load, even with a slow movement, suppression of blood inflow and outflow of the involved muscles occurs, increasing the muscle deoxygenation. In the present study, it is considered that the skin cooling, measured after the vertical handling task, is also due to vasoconstriction, potentiating the probability increase of occurrence of musculoskeletal problems. For example, one cause of shoulders' WMSD is poor blood flow in the tendons due to muscle contraction and pressure exerted by surrounding bones during tasks involving arms elevation [31].

Concerning the Pearson test, this test demonstrated that an increasing obesity level is related to a decreasing of skin temperature, but it is statistical significant ($p < 0.05$) for a few of the ROI analyzed, namely for right anterior shoulder joint (ROI 01), lower ligaments of left anterior shoulder (ROI 05) and left anterior arm (ROI 08).

As mentioned above, the decrease of skin temperature is related to the vasoconstriction occurred during muscular exercise. Negative temperature variations may present a higher risk of WMSD due to blood flow restriction. Therefore, the current investigation corroborates the established idea that obesity is a relevant and an emergent WMSD risk factor in particular in what concerns vertical handling tasks. This study also provides preliminary evidences that IRT may be an useful assessment tool in ergonomic studies. However, future studies will have to consider an increasing sample size to achieve more statistical power.

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Safety Culture and Its Contributing Factor in Education Sector in Malaysia

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Abstract. The importance of safety culture has been the focus of research attention in many sectors in Malaysia for many years in order to achieve a positive safety environment at a workplace. However, the safety culture among teachers in education sector has rarely been examined especially in school. Four factors were focused in this study; safety policies, safety procedures, safety training and safety committee as factors that leads to safety culture in school. Self-administered questionnaires that included a demographic and the factors focused in this research were used to collect data from 111 schools in Kelantan, which is one of the states in Malaysia. The number of returned valid questionnaires was 408. Confirmatory factor analysis (CFA) with Amos 19 was used to analyze the data. The measurement model shows that the four factors of situational dimensions lead to the safety culture among teachers in school. The results of the analysis indicated that safety policy, safety training and the safety committee would do well to increase the safety culture in education sector.

Keywords: Safety culture · Education sector · Situational dimension · Measurement model

1 Introduction

School environment is an environment which the students spend one third of their daily life with their teachers and students [15]. Schools have the mission of instruction as well as education on the students. Therefore, students should feel themselves in a safe environment so that effective learning occurs. There are many factors that put students at risk to injuries including poor monitoring and supervision of children, risk-taking behaviors among students, poor-decision skills among students, inadequately maintained equipment, lack of staff awareness of injury prevention, lack of conditioning especially in sports-related injuries and lack of knowledge regarding appropriate safety procedures [11].

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The specific principles are reductions in number of accidents and incidents, ensuring that safety issues receive appropriate attention, ensuring that organizational members share the same ideas and beliefs about risks, accidents, and ill related to health and, determining the style and proficiency of an organization's health and safety programs [14]. Safety defined as liberation from risk, injury and danger. In addition, safety can also be the manifestation of "caution" in order to avoid danger [8]. Culture is defined as the values and beliefs that are being shared in order to create an identity of a group of people [8]. Therefore, safe work culture can be defined as the patterns of behaviours and attitudes or products of people, which creates commitment and efficiency in an organization [8].

Safety culture plays a key function in determining an organization's success or failure [14]. A development of positive safety culture provided little guidance on how organizations might reduce the numbers of accident occurred at a workplace. A goal of positive safety culture is to create an atmosphere in which employees are aware of the risk in their workplace, continually on guard against them, and avoid taking any unsafe actions. Organizations strive for minimum accidents at workplace. Workplace safety can boost employees' performance in which workers are not burdened by the harm or danger on their wellbeing. Hence, it is important for organizations to build high safety culture at workplace.

1.1 Safety Issues in Malaysian Education Sector

During 2012–2016, the statistic of occupational accident reported in Malaysia illustrated that the increasing number of accidents in services sector and statutory bodies [3]. Table 1 shows the statistics report by Department Of Occupational Safety and Health (DOSH) in that sector. Even tough, the statistic data on accidents occurred in this sector quite low than other sector such as manufacturing, construction and others, the accidents and their consequences continue to be a major public health concern. Newspaper keeps reporting on many accident cases occurred in education sector showing the level of safety culture in this sector especially in education sector is quite low. Table 2 shows a summary of the literature on the newspaper report on the types of accidents occured in school environment from year 2015 to end of 2016.

Table 1. The number of accidents (reported and investigated) in the services sector and statutory bodies in Malaysia from 2012 to 2016

Year	No. of accidents	Fatal	Without permanent disabilities	Permanent disabilities
2012	54	4	49	1
2013	67	0	67	0
2014	25	5	20	0
2015	32	0	31	1
2016	110	6	101	3

Table 2. Types of accident occur in the Malaysian school

Type of accidents	No. of cases
Crushed by heavy objects	11
Pierced by share objects	3
Stung by venomous animals	1
Chemicals and laboratory equipment were damaged	8
Struck by vehicle	1
Fall from the building	7
Perform activity	2
Total	33

Occupational Safety and Health Act (OSHA) 1994 stated that the self regulation concept was promulgated based on the primary responsibility of ensuring safety, health and welfare of all persons at all places of work. Therefore, an introduction of safety culture can be seen as a systematic solution towards the establishment of zero accidents in the workplace [18]. The Malaysian Occupational Safety and Health Act 1994 (OSHA 1994) provides a legislative framework to promote, stimulate and encourage high standards of safety and health at workplace. The aim of the act is to promote safety and health awareness and establish effective programmes to suit the industries needs and implementation of the law through self-regulation schemes is designed to suit particular organization. The long-term goal of the act is to create a healthy and safe working culture among all Malaysian employees and employers. A school is considered a place of work. In the OSHA 1994, "place of work" means premises where persons work or premises used for the storage of plant and substance. Therefore, students and teachers are not left behind [13].

Therefore, duties of the teachers are to ensure safety and avoid existing hazards teacher and students at school environment. According to this scenario, this study was carried out to measure the factors that contribute to the safety culture school teacher in Malaysian in order to get more input on the condition of safety culture in malaysian education that causes so many cases of accidents among teacher and students in school.

1.2 Safety Culture in Its Contributing Factors

Many debates have emerged among researchers on the definitions of safety culture. This paper particularly adopts definitions by [2] in which safety culture reflects the attitudes, beliefs, perceptions, and values that employees share in relation to safety. The Reciprocal Safety Culture Model presents an integrative way of thinking about many processes that impact on safety culture, a set of measurement techniques that do not depend solely on incident or accident index and, a dynamic framework that can be performed a multilevel analysis of the safety culture. It also emphasized that the safety culture can be measured by examining the reciprocal interaction between safety management systems; people perceptions about safety and people's actual safety related behavior [2]. The organizational dimension can be measured via safety management systems audits/inspections where it analyzed the structure of management systems, policies and working procedures [1]. An intention of this study was focused on organizational/situational dimension (safety management systems), which are safety procedure, safety policy, safety training and safety committee; in order to see how the management system especially related to safety in school can contribute towards safety culture in school. The study focused the investigation on examining whether all the factors can contribute to teachers' safety culture at school. Enhancing safety culture is important to the success of health and safety at work.

Employees who abide by safety regulations will establish an organization that has an improved safety culture [10]. Employees did not have experience in any of the incidents and accidents while performing their duties when they comply with any regulations, procedures and instructions while performing the task [14]. Safety training can help to raise awareness and efficiency of employees and related parties to work safely and to foster a positive safety culture within the organization [4]. It is the key to success in any organization for the prevention of accidents at work [16]. Safety committee is an effective strategy to create a safe workplace as they are the one involved in the daily operation of the workplace where safety is constantly an issue [9]. Safety committee can provide a channel for employee to provide their input on safety issues affecting them and this will reduce accidents at the workplace [6, 9]. The framework of this study is illustrated in Fig. 1.

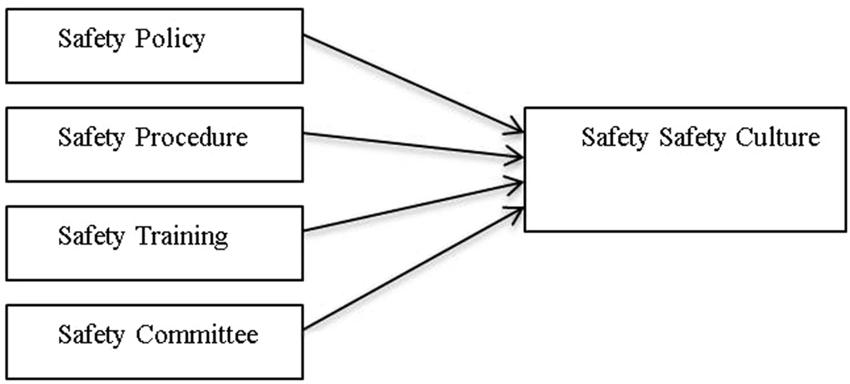

Fig. 1. Conceptual framework of situational dimension and safety culture

2 Method

An intention of this study was focused on four variables such as safety policies, safety procedures, safety training, safety committee that contributes to safety culture, we utilized a quantitative approach. We developed a questionnaire that was adapted from previously published questionnaires addressing the issues on variables of our interests. The measurement model was estimated by structural equation modeling (SEM), which is a powerful multivariate technique for analysing causal models. The measurement model is estimated using confirmatory factor analysis (CFA) to test whether the latent variables possess sufficient construct validity.

2.1 Sample description

The questionnaire was adapted from a survey questions by [4, 8, 14, 16, 18]. Each item was measured on a five point Likert scale, ranging from strongly disagree (= 1) to strongly agree (=5). Data were collected from 408 teachers from 111 public schools in Kelantan, Malaysia using stratified random sampling. The participants in this study were teachers from both primary and secondary schools from every district of Kelantan.

2.2 Reliability

To examine the internal consistent reliability of the observed item questionnaire, Cronbach's alpha was assessed. The resulting alpha values ranged from .847 to .917, which were above the acceptable threshold, as shown in Table 3.

Table 3. Estimates of the measurement model

Construct	Item	Factor loading	Cronbach's alpha	CR	AVE
Safety Policy (POL)	POL1	0.760	.888	0.890	0.670
	POL2	0.834			
	POL3	0.875			
	POL4	0.801			
Safety Procedure (PROC)	PROC1	0.717	.847	0.850	0.532
	PROC2	0.718			
	PROC3	0.769			
	PROC4	0.775			
	PROC5	0.661			
Safety Training (TRAIN)	TRAIN1	0.700	.874	0.882	0.560
	TRAIN2	0.571			
	TRAIN3	0.804			
	TRAIN4	0.859			
	TRAIN5	0.772			
	TRAIN6	0.749			
Safety Committee (SC)	SC1	0.508	.917	0.920	0.565
	SC2	0.679			
	SC3	0.855			
	SC4	0.809			
	SC5	0.853			
	SC6	0.798			
	SC7	0.728			
	SC8	0.731			
	SC9	0.740			

3 Results

3.1 Assessment of the Measurement Model

The measurement model was assessed by confirmatory factor analysis (CFA). According to [12], the measurement model should be evaluated first before generating the best overall model fit. The measurement model was evaluated using confirmatory factor analysis to assess the factorial validity of the measurement model. The values for composite reliability (CR) and average variance expected (AVE) were needed in order to obtain the divergent validity. [17] suggest that the recommended threshold of average variance extracted is 0.5, while [5] suggest that the recommended threshold of composite reliability should be greater than 0.7. All composite reliabilities measures of constructs exceed the recommended threshold of 0.7. The factor loadings that are

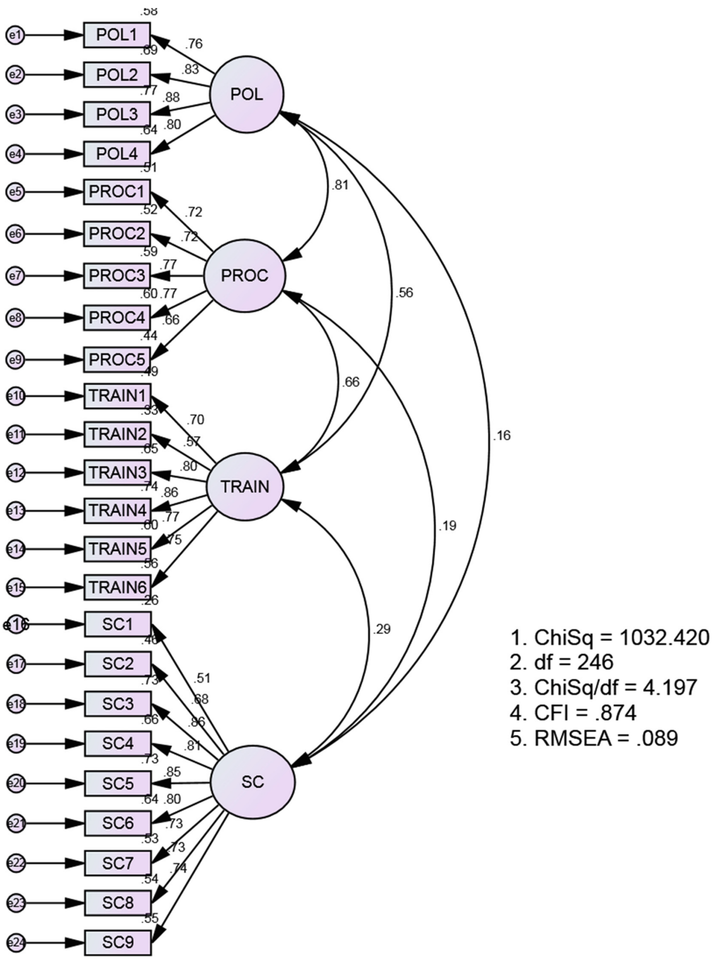

Fig. 2. Measurement model of situational dimension of safety culture

smaller than the recommended level of 0.5 should be removed. Discriminant validity can be tested by comparing the square roots of the AVE with the correlations among the constructs. All of the square roots of the AVE by constructs were greater than the correlation among constructs as shown in Table 3, so discriminant validity was supported. In brief, the measurement model assessment, including convergent and discriminate validity measures, was satisfactory. The overall model fit was assessed in terms of four measures. These indices included: the chi-square/degree of freedom (χ^2/d.f), the traditional chi-square (CMIN), the degree of freedom (DF), the Comparative Fit of Index (CFI) and the Root Mean Square of Error Approximation (RMSEA) [5] to obtain a model fit. The CFI value must exceed 0.90 and the RMSEA value must be lower than 0.08 [5] in order to obtain an acceptable fit with the data and the χ^2/d.f should not exceed 3. Accordingly, all the fitness measures in this research fell into acceptable ranges using CFA. Consequently, the proposed model provided a suitable fit.

We estimated the proposed model by using structural equation modeling with the maximum likelihood estimation method. The chi-square goodness- of- fit test showed that the model did not fit the data well, ÷2 = 1032.420. Although the model did not fit well by the chi-square test, the baseline comparisons fit indices of CFI were close to or exceeded 0.9 (CFI = 0.874) and the ratio chi-square/d.f. is 4.197. The RMSEA showed a value of 0.089 indicating a good model fit. Accordingly, the recommended thresholds and results of the measurement model fitness indicate a good model fit. Figure 2 shows the results of the measurement model.

4 Discussion and Recommendations

This study was conducted to assess the reliability and validity of the factors contributing to safety culture among teachers in education sector by applying confirmatory factor analysis to a Malaysian case. The results of the CFA provided support for a four-factor model situational dimension of safety culture. Results suggested that the four-factor model was the best overall fit to the data. Four indicators related to safety policy, safety procedure, safety training and safety committee represented the situational dimension.

5 Conclusion

In conclusion, this study added to the body of literature about safety culture and its contributing factors. The results of this study emphasizes on the importance of safety policy, safety training and safety committee to increase safety culture among schoolteacher. In generalizing the study results, however, we need to be cautious due to the limitation: the data were collected only from primary and secondary school in Kelantan whish is one of the states in Malaysia. Despite the limitation, the results of this study can be used by Education Ministry of Malaysia specially the school management to gain knowledge on the importance of safety training and safety committee to increase safety culture at workplace. The Ministry of Education also could play more important role in the primary prevention of accidents and injuries as well as promotion of Safety and Health in schools through advocacy, data collection and education as well as of research to address this problem. Safety culture is a main goal of most companies, especially those with high risks workplace like manufacture companies. Laboratories and workshops in schools is a risky place and require more attention from the management to make this a better place to work safely. Safety culture among teachers in education environment, which is school, plays an important role in making education sites a safer and healthier place to work for them and for students to learn. Finally, we call future research to address aspects that were not included in this study, to better evaluate the safety issues at school environment.

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Dynamic Fuzzy Safety Analysis of an Industrial System

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Abstract. In many industrial systems, equipment failures and worker accidents result from contributing events which occur in a certain sequence in time. These events must be analyzed, assessed and prioritized. This endeavor can be hindered by the fact that, in real life, often, the data associated with these events are not known precisely. Fuzzy numbers, provide a method for taking into account the uncertainty problem. Dynamic fault trees and Markov analyses, on the other hand, provide a means of handling the sequential character of events which can lead to work accidents. Thus, in this paper, a system safety analysis is performed using fuzzy dynamic fault tree method and Markov analysis. A simple example is used to demonstrate this approach. In the first part of this paper, the relevant dynamic fault tree and Markov diagram are drawn and the fuzzy probability of occurrence of the accident under consideration is evaluated. The probability is calculated, not on the basis of theoretical values but, rather, on qualitative evaluation given by press brake operators in the field.

Keywords: Fuzzy Markov chain · Dynamic fault tree

1 Introduction

Traditional fault tree analysis takes a static view of the system; that is, the sequence in which the events leading to the undesirable event happens is not taken into account. Sometimes the sequence is important in determining the outcome. For example, consider the operation of a power press. If the protective device fails before the operator reaches into the hazardous zone of the machine, the operator may not be aware of it and the machine may not be set-up to stop in case of such a failure. In that case, the motion of the press may not be stopped and the operator's arms and hands may be caught in the closing dies of the press. If, on the other hand, the failure of the device occurs after the operator reached in the press, the hazardous motion may have stopped and the failure will not have initiated any further motion. Thus, no accident occurs. A traditional fault tree analysis would not have differentiated these two sequences. To remedy this deficiency, several approaches have been proposed. In [1], Dugan et al. have used an approach by which sub-trees are identified with dynamic gates. In [2], Amari proposed

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a method where the dynamic fault tree is solved without converting it to a Markov model. In [3], Bobbio et al. have used a Bayesian network-based approach to solve the problem.

All these approaches can evaluate the dynamic fault tree under consideration but they assume that failure data or states of the systems are known and can be expressed with exact values. But uncertainties and difficulties in obtaining data are a common difficulty.

Fuzzy set theory first proposed by Zadeh [4], has proven to be a useful methodology to cope with these cases where uncertainty and scarcity of data are important features.

Li et al. [5], have solved a dynamic fault tree problem by solving the associated Markov state equations, with fuzzy numbers in the context of the reliability analysis of the hydraulic system of a CNC machining center. However, the origin of the fuzzy data used in the paper is not explained. Mechri et al., in [6] have used fuzzy Markov chains to analyze the reliability of Safety Instrumentation Systems. The data they used were provided by one expert. However, the process by which the expert's opinion was solicited is not explained. In this paper, a dynamic fault tree and its associated fuzzy Markov chain is solved in the case of a different type of industrial system, a brake press operation, using data collected from experts.

Furthermore, in these works, the human element in the operation of these equipments and systems is not considered. In this paper, on the other hand, we solve a fuzzy Markov diagram model which represents the safety of a brake press operation. Besides the machine failure, a human factor failure is also considered.

2 Forward Problem

The term «forward» refers to the process of evaluating the top event of a fault tree starting from the bottom events, with everything being done in terms of fuzzy numbers (Fig. 1).

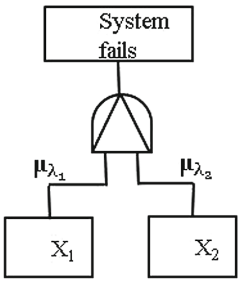

Fig. 1. Dynamic fault tree.

2.1 Fuzzy Dynamic Fault Tree (FDFT)

A dynamic fault tree is one which contains considers the sequential nature of events which are related to the system under consideration. Referring to the figure showing a general situation involving just two components, instead of using static AND gates as in a traditional static fault tree, a dynamic fault tree uses a PAND gate whose output changes to a failure state only if all of its inputs have failed in a predetermined order. Thus, in the example shown in the figure, failure 1 occurs before event 2. When these two events occur in that sequence, the top event of the fault tree, «system fails», occurs. The opposite sequence, failure of component 2, X_2, arising before failure of component 1, X_1, does not lead to the top event. One of the uses of fault trees is to calculate probabilities of occurrences of the failures or events represented in the fault tree in question. A fuzzy dynamic fault trees involves probabilities expressed as fuzzy numbers.

2.2 Fuzzy Markov Chain (FMC)

From a dynamic fault tree, a so-called Markov diagram can be drawn. This enables one to write a first-order differential state equation which can then be solved.

Markov analysis is a technique used for modeling system state transitions and calculating the probability of reaching various system states from the model, [7].

In a Markov model, a system is supposed to possess a given number of states, each defined by a set of variables. The transitions from one discrete state i to state j are considered to occur at transition rates λij. In a fuzzy Markov model, these transition rates are expressed as fuzzy numbers. Fuzzy numbers are introduced to reflect the fact that the possibility of a transition from one state of a system to another state is uncertain. Markov Chains are used mainly in reliability studies involving failures of components but can also be used in relation to human interactions with engineered systems.

2.3 Calculation of the Top Event of the Dynamic Fault Tree Using the Fuzzy Markov Model

Conversion Between Normal Probability Distribution and Fuzzy Triangular Numbers

In risk analysis, we often do not know the precise values of the probabilities of occurrence or of failure of the systems or of its components. One way to deal with this problem is to consider that the variables of interest follow a normal probability distribution with a mean value and a standard deviation. However, another approach to the problem is to use fuzzy triangular numbers.

A fuzzy number is represented by three numbers $<a_1, a_2, a_3>$. Its mathematical form and graphical shape can be given as this (Fig. 2):

$$\mu_A(x) = \begin{cases} 0 & x < a_1 \\ \dfrac{x - a_1}{a_2 - a_1} & \text{for } a_1 \le x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} & \text{for } a_2 \le x \le a_3 \\ 0 & x > a_3 \end{cases}$$

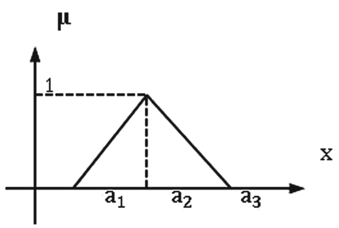

Fig. 2. Triangular fuzzy number.

In this representation, a_2 corresponds to a membership value of 1 meaning that we think that the most probable value of the variable under consideration is a_2. So a_2 corresponds to the mean value in a normal probability distribution. In this representation, we mean also that the variable under interest lies between the values a1 and a3, which have "membership values" of 0. In other words, a_1 and a_3 resemble the 3σ values from the mean in a standard normal probability distribution. For example, it might be ascertained that the probability of failure of a given component is «around 0.0007». This information could be expressed as a fuzzy number such as <0.00065, 0.00070, 0.00075>. What this means is that we believe that the actual probability in question is most likely equal to 0.00070 but we do not believe that it could equal a value as low as 0.00065 or a value as high as 0.00075.

Fuzzification

In the FDFT method adopted in this work, the fuzzy probabilities associated with the basic events forming the fault tree under study are needed for the calculation of the top event probability. These probabilities are often expressed in terms of qualitative linguistic statements such as «the probability of this occurrence is thought to be low, or high, or somewhat low, etc.». For calculation purposes, these statements must be translated into fuzzy numbers (triangular in this study). This process is generally called fuzzification in the literature.

3 Example

As a way of illustrating the theory, brake press operation will be considered. Before delving into calculations, a brief overview of the process involved will be given. A press brake is a machine commonly found in the metal manufacturing industry. It is used to bend sheet metal in different shapes. A typical press brake is illustrated here (Fig. 3):

Fig. 3. Press brake.

The machine is composed of two main structural components, a top beam mounted on a plate and a bottom table. These two parts are usually connected by two C-frames on each side of the machine. Dies are clamped on the top and bottom parts. Either the top or the bottom half of the press then closes in (via a hydraulically-powered mechanism) on the stationary part. The operator holds the piece-part and actuates the closing motion with a foot pedal, in most applications. A hazardous situation is thus created from the proximity of the worker's hands to the press closing motion. A possible undesirable event (often called a hazardous event) in such a situation is then that the worker gets his hands caught between the closing dies (the hazardous zone of the machine).

Safety regulations and standards require that such machines be equipped with protective devices which either prevent entry of the operator in the hazardous zone or stop the hazardous motion when parts of the worker's body are in the hazardous zone. The protective device often utilized with press brake takes the form of a light (laser) sensor beam which spans the length of the press and is mounted between the two dies. Such a device is shown in the above picture of a press brake (1 is the sensor beam and 2 refers to the emitting and receiving components of the device).

From this general description, a simple fault tree can be drawn (Fig. 4).

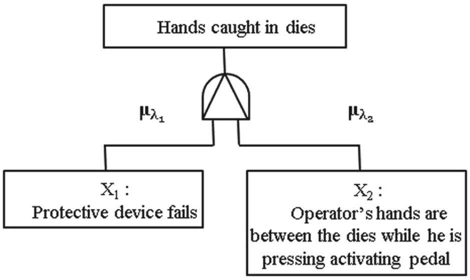

Fig. 4. Fault tree.

In this example, the top event occurs if two events arise. One of these consists of the worker not withdrawing his hands from between the dies. In practice, such accidents have occurred due to contributing factors such as, for example, worker fatigue due to high job repetition leading to loss of concentration, stressful work situations, very noisy or hot and humid work environment. These factors would appear in the fault tree below event X_2.

The fault tree is indeed dynamic in nature as per our definition because event X_1, protective device failure, must occur before the bending action by the worker; otherwise a properly functioning device would stop (safely) the press and no accident then occurs.

The equivalent associated Markov diagram is then (Fig. 5):

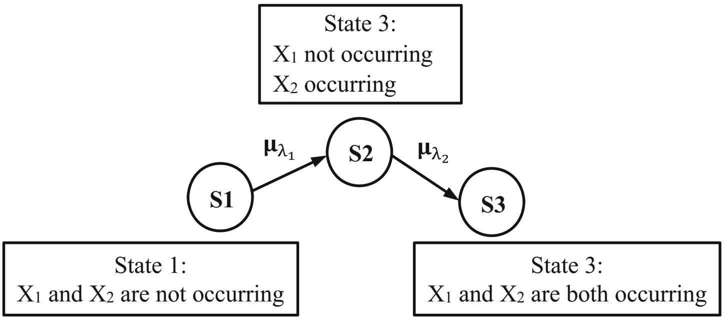

Fig. 5. Markov diagram.

The equations of state are then:

$$\frac{d\mathbf{P}}{dt} = \begin{bmatrix} \boldsymbol{\mu}_{\lambda_1} & 0 & 0 \\ \boldsymbol{\mu}_{\lambda_1} & \boldsymbol{\mu}_{\lambda_2} & 0 \\ 0 & \boldsymbol{\mu}_{\lambda_2} & 0 \end{bmatrix} \begin{bmatrix} \mathbf{p}_1 \\ \mathbf{p}_2 \\ \mathbf{p}_3 \end{bmatrix}$$

or

$$\frac{d\mathbf{P}}{dt} = \mathbf{Q}^T\mathbf{P} \tag{1}$$

Solving with Symbolic MATLAB, we obtain the expression for the probability:

$$\mathbf{P} = 1 - \left[\left(1 - \frac{\boldsymbol{\mu}_{\lambda_1}}{\boldsymbol{\mu}_{\lambda_1} - \boldsymbol{\mu}_{\lambda_2}} \right) e^{-\boldsymbol{\mu}_{\lambda_1} t} + \left(\frac{\boldsymbol{\mu}_{\lambda_1}}{\boldsymbol{\mu}_{\lambda_1} - \boldsymbol{\mu}_{\lambda_2}} \right) e^{-\boldsymbol{\mu}_{\lambda_2} t} \right] \tag{2}$$

where:

P = Probability of failure expressed as a fuzzy term;
$\boldsymbol{\mu}_{\lambda_1}$, $\boldsymbol{\mu}_{\lambda_2}$ = fuzzy failure rates of events X_1 and X_2;
t = time which must be set, i.e. we consider the state of the system after t hours.

We calculated **P** with the following data:
We shall take t = 50000 h.

Calculation of the probability of occurrence **P** of the accident requires knowledge of the failure rates (expressed as fuzzy numbers). Specifically what is needed are: the failure rate of the protective device and, the failure rate associated with the human action consisting in having one's hands between the press dies while the operator is bending a part. The first data could, in principle be obtained from the manufacturer of the device. However, in practice, this data may not necessarily exist. In the same manner, the number of times a press brake operator places his hands between the dies of a press is not a statistic that is collected by workplaces. So, a another way to obtain the data is through expert elicitation, that is consulting people knowledgeable with the problem at hand and asking them to estimate, based on their judgement, the probabilities or failure rates that are sought.

Participants were thus solicited for this purpose. These were eight bending press operators in a large manufacturing plant. The health and safety coordinator as well as the workers' supervisor were also solicited. A structured questionnaire was used in the elicitation process.

The final aggregated fuzzy estimate of the probabilities is obtained by simply taking the average of the experts' estimates for each of the three components of the fuzzy numbers corresponding to the expert's linguistic probability estimate, as given in the scale.

With the final fuzzy probability estimates then on hand, the top event in the relevant fault tree is calculated. The fuzzy failure rates are calculated as $\boldsymbol{\mu}_1 = <2.1203, 2.7100, 2.7871> \cdot 10^{-5}$ and $\boldsymbol{\mu}_2 = <0.53434, 1.0306, 1.2963> \cdot 10^{-5}$.

Inserting those values into Eq. (2), we obtained $\mathbf{P} = <0.0932, 0.1944, 0.2380> \cdot 10^{-5}$.

4 Conclusion

In this paper, we presented a method for calculating the top event probability of occurrence of a dynamic fuzzy fault tree, a process which can be referred to as a forward problem. The fault tree models the dynamic aspect of the problem at hand, namely that the top undesirable event occurs depends on the time sequence in which the initiating events occur. A Markov diagram was derived which allows the appropriate equations of state to be written. Solving them then yielded the desired probability.

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Implementation Proposal of OH&S Management System According to the Standard ISO/DIS 45001

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Abstract. Enhancing the safety and health at work has significant economic importance, as addressing issues related to safety and health to create favourable work conditions and work relations brings optimization of work process and a positive economic effect. It also brings reduction of losses, greater productivity, efficiency and quality of work – that means greater prosperity for the company and the whole society. To ensure the continuous prosperity of the company, it is important to implement a control mechanism to ensure the proper functioning of the business entity. There is a general principle that only 15% of problems should be left to be solved by employees and 85% should be secured by a management system. As in other areas of business management, also in occupational health and safety, it is necessary to establish an effective management system. An example is the standard OHSAS 18001:2007, which aims to systematically limit the occupational risks that may endanger the safety and health of all persons affected by activities, products or services of the organization. The aim of the standard is to help organizations manage occupational health and safety (hereinafter OH&S) risks and improve product quality or services and organizational performance by preventing injuries and occupational diseases. This article presents the pilot version of implementation of OH&S management system in a manufacturing organization where the management decided to adopt this new structure and implement a project of the preparation of the implementation according to the requirements of the new standard ISO 45001:2017.

Keywords: OH&S management system · International standards · Safety

1 Introduction

With the growing number of many different management systems, the issue of their successful implementation and continual meeting of the requirements has been increasingly coming to the foreground. According to [1], there are several factors supporting effective implementation of systems. On one hand, it is about maturity of an organization, number of processes; on the other hand, as it is reported [10], involvement of management plays an equally important role. Throughout the history, it is clear

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that efforts to introduce the requirements of individual management systems were based on specific requirements that were not yet unified.

In 1989 European Union adopted the Framework Directive no. 89/391/EEC on implementation of measures to improve OH&S. It represents an important binding milestone in improving safety and health protection at work and ensures minimum requirements for safety and health protection throughout Europe. Thus the member states may maintain those measures or introduce more stringent measures.

It defined precautionary principles, general duties of employers and employees. In response to it, the implementation non-statutory guidelines were issued to cover the requirements for the OH&S workers, working conditions focusing on work equipment, work environment, personal protective equipment, handling of loads, work with display screens, asbestos, chemicals, etc. The OH&S area was complex; therefore an effective management system of OH&S was introduced that ensured the safety of production equipment (e.g. in compliance with the Directive 89/392/EEC on the safety of machines, now 2006/42/EC) besides the OH&S staff and the interested parties.

The year 1996 can be considered as the beginning of development of the OH&S management system, in which time the first British Standard - BS 8800 in this area was adopted. The need for individual criteria on health and safety at work resulted in the BS 8800 standard to become a kind of internationally accepted standard as a basis especially in Europe in the 1990s.

In 1999, this trend led to the adoption of the international document **OHSAS 18001**, supplemented with the Implementation Guidelines - OHSAS 18002 in 2000. Even though this document was not a formal international standard at that time, it was providing guidance on appropriate procedural and organisational principles of OH&S [3].

In June 2007, the BS OHSAS 18001:2007 standard (British Standard Occupational Health and Safety Assessment Series) was issued in the UK. This standard replaced the specification of the 1999 – OHSAS 18001:1999 standard and there were a few significant changes related to the old standards operated by 80 countries of the world. The standard applied to prevention, improvement of work health and safety management system, identification of hazards and threats, risk assessment, and determining management measures, communication and consulting and it has been structured so as to be compatible with the standards related to the quality management system (QMS) and Environmental Management System (EMS). Still, it was only a recommended standard, which was issued as an international ISO standard.

The area of safety has always been perceived differently in various countries, respectively, health protection has been viewed through a socio-cultural prism. However, this fact did not discourage the members of ISO from seeking a common concept of security, which could be defined as a unified international ISO standard. Therefore, the OHSAS 18001 standard has been effective for several years now in the review process to be issued under the name ISO 45001 as a completely new, internationally renowned standard throughout the world. This standard has already had several announced releases; however, it has always been postponed due to the comments and implementation Fig. 1 [9].

The initial issue period was already announced for 2016, but the International Standards Organisation moved this term with the fact that it released a draft version for the public, marked as ISO/DIS 45001. The aim of this draft version is to give

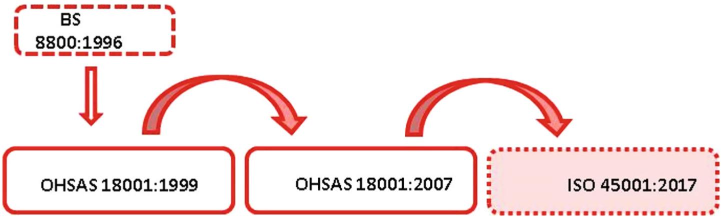


Fig. 1. Historical development of the OHSAS 18001 standard

organizations time to become familiar with the new requirements in advance, and thus prepare them for a smooth transition from the old system to the new occupational health and safety management. Based on the statistics by ILO, one person dies or 153 people are injured every 15 s in the world as a result of an accident or occupational disease. Accidents at work represent a heavy burden for organisations and society as a whole - it is about 2.3 million deaths each year and more than 300 million non-fatal accidents [4].

This is also one of the reasons why the planned ISO 45001 standard is one of the most anticipated ISO standards for OH&S. With its arrival, a minimum increase in the workplace safety standard, as well as reduction in the number of accidents are expected.

2 Comparative Study of the OHSAS 18001 and the Upcoming ISO 45001 Standard

In 2012, ISO issued a document marked as Annex SL (Proposals for Management System Standards). Annex SL - Proposals for management systems standards according to which all international newly adopted or revised standards shall have a uniform HLS (High Level Structure) framework based on the Plan - Do - Check methodology.

The reason for issuing the Annex SL was to seek formal unification of all management systems standards by providing a uniform structure.[1] According to Annex SL, all international standards of management systems shall have a uniform structure in form of ten chapters:

Introduction

1. Scope
2. Normative References
3. Terms and Definitions
4. Context of the Organization
5. Leadership

[1] Despite the uniform structure, there are visible formal differences. For example the ISO 9001 standard is marked as the Chapter 5 Leadership. ISO/DIS 45001 refers to the Chapter 5 titled as Leadership and Worker Participation.

6. Planning
7. Support
8. Operation
9. Performance Evaluation
10. Continual Improvement

The benefit of HLS structure will be to facilitate the integration of management systems in the organization. As already mentioned, the Annex SL is based on the PDCA cycle. Chapters 4–7 are included in the Plan phase, Chapter 8 in the Do phase, Chapter 9 in the Check phase, and the Chapter 10 in the Act phase [2]. The section Planning involves Risk Based Thinking, which must be applied in all processes of the management system.

Like all other management systems standards, the OH&S management system standard has undergone the HLS application, changes of requirements that did not occur in the original OHSAS 18001 at all (Fig. 2).

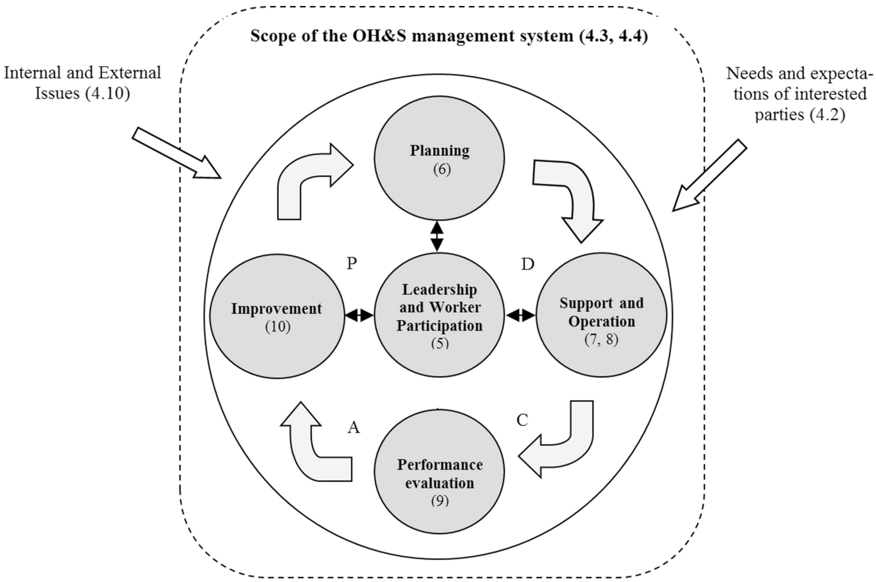


Fig. 2. OH&S management system model based on ISO/DIS 45001 [7]

2.1 Major Changes in the Requirements of the ISO/DIS 45001standard

In addition to the introduction of the main system requirements (Table1.), new terms and definitions referred to in the standard were formulated within the OH&S management system standard. These are primarily terms, such as:

Interested party - person or organization that can affect, be affected by, or perceive its self to be affected by a decision or activity.

Table 1. Comparison between the requirements of the OHSAS 18001 and ISO/DIS 45001 standard [5]

ISO/DIS 45001:2016	OHSAS 18001:2007	Explanation
Introduction		
Introduction 0.1 Background 0.2 Aim of an OH&S management system 0.3 Success factors 0.4 Plan-Do-Check-Act cycle 0.5 Contents of this International Standard	Introduction	The point of both sections is the same: explaining the purpose of the standard and emphasizing the PDCA cycle. ISO 45001 provides more information on the purpose and benefits of an OH&S management system and defines success factors for an effective OH&S management system. The last sub clause of this section provides clarification of the structure and terms of the standard
1 Scope		
1 Scope	1 Scope	These clauses are almost the same for both standards
2 Normative references		
2 Normative references	2 Reference publications	ISO/DIS 45001 has no normative references
3 Terms and definitions		
3 Terms and definitions	3 Terms and definitions	Both standards provide definitions for terms used in the text
4 Context of the organization		
4.1 Understanding the organization and its context		This is a completely new requirement; the organization will need to determine the external and internal context that affects the organization and its OH&S management system
4.2 Understanding the needs and expectations of workers and other interested parties		Interested parties are mentioned several times in OHSAS 18001, but there were no explicit requirements for their identification and identification of their needs and expectations. Furthermore, ISO/DIS 45001 distinguishes workers from other interested parties in order to emphasize their importance
4.3 Determining the scope of the OH&S management system	4.1 General requirements	Both standards require definition of OH&S management system scope; only ISO/DIS 45001 elaborates requirements for the scope in more detail. Documenting the scope of the OH&S management system is required by both standards. For more information, see How to determine scope of the OH&S management system
4.4 OH&S management system and its processes	4.1 General requirements	The requirements are the same for both standards

(*continued*)

Table 1. (*continued*)

ISO/DIS 45001:2016	OHSAS 18001:2007	Explanation
5 Leadership and worker participation		
5.1 Leadership and commitment	4.4.1 Resources, roles, responsibility, accountability and authority	Both standards have similar requirements regarding top management. ISO/DIS 45001 does not require the organization to appoint a member of the top management to be responsible for the OH&S management system
5.2 OH&S policy	4.2 OH&S policy	The requirements for the OH&S Policy are the same in both standards, only better elaborated in ISO/DIS 45001
5.3 Organizational roles, responsibilities, accountabilities and authorities	4.4.1 Resources, roles, responsibility, accountability and authority	The main difference is that the new standard does not require appointing a management representative
5.4 Participation and consultation	4.4.3.2 Participation and consultation	The requirements of both standards are almost the same; only ISO/DIS 45001 defines them in more detail
6 Planning		
6.1 Actions to address risks and opportunities		
6.1.1 General		This is a completely new requirement compared to OHSAS 18001. When planning the OH&S management system, the organization will need to determine the risks and opportunities affecting the organization
6.1.2 Hazard identification and assessment of OH&S risks	4.3.1 Hazard identification, risk assessment and determining controls	
6.1.2.1 Hazard identification		The requirements regarding identification and assessment of OH&S hazards are the same in both standards; only ISO/DIS 45001 provides more details
6.1.2.2 Assessment of OH&S risks and other risks to the OH&S management system		Risks related to the OH&S management system are a new requirement compared to OHSAS 18001; this clause covers not only hazard-related risks but also risks regarding legal and other requirements and overall context of the organization
6.1.2.3 Identification of OH&S opportunities and other opportunities		Opportunities are only mentioned in ISO/DIS 45001, and this sub clause defines what kind of opportunities must be addressed
6.1.3 Determination of applicable legal requirements and other requirements	4.3.2 Legal and other requirements	Both standards require the organization to establish a process for identification of legal and other requirements, and also to document legal and other requirements

(*continued*)

Table 1. (*continued*)

ISO/DIS 45001:2016	OHSAS 18001:2007	Explanation
6.1.4 Planning to take action		The organization will have to plan actions to address the determined risks related to threats and opportunities and evaluate their effectiveness
6.2 OH&S objectives and planning to achieve them 6.2.1 OH&S objectives 6.2.2 Planning to achieve OH&S objectives	4.3.3 Objectives and programs	The requirements remain the same, but are further elaborated in the new version. See the sample document here: OH&S Objectives and Programs
7 Support		
7.1 Resources	4.4.1 Resources, roles, responsibility, accountability and authority	The requirements regarding resource provision for both standards are the same, but the new standard emphasizes resource provision by dividing them into separate clauses
7.2 Competence 7.3 Awareness	4.4.2 Competence, training and awareness	The requirements are the same, only further outlined in ISO/DIS 45001 by division into separate clauses
7.4 Information and communication	4.4.3.1 Communication	The requirements of both standards are pretty much the same, only elaborated in more detail in ISO/DIS 45001
7.5 Documented information 7.5.1 General 7.5.2 Creating and updating 7.5.3 Control of documented information	4.4.4 Documentation 4.4.5 Control of documents 4.5.4 Control of records	Documents and records now belong to the same category – documented information. The requirements of both standards are equivalent
8 Operation		
8 Operation	4.4 Implementation and operation	
8.1 Operational planning and control	4.4.6 Operational control	Requirements of both standards are pretty much the same; only ISO/DIS 45001 has separate sub clauses for change management and outsourced processes
8.1.2 Hierarchy of controls	4.3.1 Hazard identification, risk assessment and determining controls	The hierarchy is much better defined in ISO/DIS 45001 and slightly modified. While OHSAS 18001 puts it inside the clause with other requirements, ISO/DIS 45001 has it separately to emphasize its importance
8.1.2 Hierarchy of controls	4.3.1 Hazard identification, risk assessment and determining controls	The hierarchy is much better defined in ISO/DIS 45001 and slightly modified. While OHSAS 18001 puts it inside the clause with other requirements, ISO/DIS 45001 has it separately to emphasize its importance

(*continued*)

Table 1. (*continued*)

ISO/DIS 45001:2016	OHSAS 18001:2007	Explanation
8.2 Management of change 8.3 Outsourcing 8.4 Procurement 8.5 Contractors	4.4.6 Operational control	The requirements of both standards are almost the same, only elaborated in more detail in ISO/DIS 45001 and kept as a separate clause
8.6 Emergency preparedness and response	4.4.7 Emergency preparedness and response	The requirements are almost the same, but are further elaborated in the new standard
9 Performance evaluation		
9 Performance evaluation	4.5 Checking	
9.1 Monitoring, measurement, analysis and evaluation 9.1.1 General	4.5.1 Performance measurement and monitoring	The new clause sublimates all requirements monitoring and measuring, including legal and other requirements, OH&S performances, operational controls, etc
9.1.2 Evaluation of compliance with legal requirements and other requirements	4.5.2 Evaluation of compliance	The requirements are the same. See the sample document here: Compliance Evaluation Record
9.2 Internal audit	4.5.5 Internal audit	The requirements are equivalent, but the new standard has divided the clause into two sub clauses to emphasize some elements of the internal audit, such as the audit objective and the audit process. The main difference is that the new standard does not require a documented procedure
9.3 Management review	5.6 Management review	The requirements are equivalent
10 Improvement		
10.1 Incident, nonconformity and corrective action	4.5.3 Incident investigation, nonconformity, corrective action and preventive action 4.5.3.1 Incident investigation 4.5.3.2 Nonconformity, corrective action and preventive action	ISO/DIS 45001 does not have preventive actions, which aligns it with new versions of other management system standards. Also, incident investigation is merged with nonconformities and corrective actions because the same process can be used for investigation of incidents and nonconformities, and they are both resolved with corrective actions
10.2 Continual improvement		The new standard points out the need to use all available information for continually improving the OH&S management system
Annex A – Guidance for use		Annex A explains the new structure of the ISO/DIS 45001 standard, together with explanations of each clause and its requirements

Competence - ability to apply knowledge and skills to achieve intended results.

Documented information - information organizations are required to control and maintain, including the medium on which information is contained.

Top management - person or group of people who direct and control an organization at the highest level.

Injury and ill health - adverse effect on the physical, mental or cognitive condition of a person [8].

For explanation and a successful implementation (especially in cases where organizations have already implemented OH&S management system) it is necessary to compare the requirements listed in the previous version of a standard with the upcoming version of standard (Table 1).

Prepared ISO 45001 will replace OHSAS 18001 and current users of OHSAS 18001 will need to update their systems according to the requirements of the new international health and safety standard within a three-year transition period that will commence after the standard is published for use [8].

Following from the requirements of ISO/DIS 45001, it is possible to identify several essential changes, which will have to be applied by organizations.

Summary of key changes [7]:

- Strategic approach to OH&S management
- New Stages in the development of the Management System involving defining the Structure, Normative Mandatory References, Common Terminology and defining the Scope before developing the System.
- New stage focussing on the “Context” of the organisation including understanding the internal and external drivers and assessing the needs of interested parties
- A greater emphasis on the integration of OH&S into the management of the business
- Greater involvement and emphasis on senior management’s leadership commitment and on internal consultation and representation
- More emphasis on the concept of risk management
- Legal and other requirements to be made more explicit
- Greater focus of need to demonstrate compliance
- Greater emphasis on hierarchy of controls
- Management of change specifically included
- Outsourcing, contractor management and procurement arrangements to be made more explicit
- An increased flexibility with the use of documents.

3 Application of New the Requirements of ISO/DIS 45001 in a Selected Company

The implementation proposal was carried out in an organization with several successfully implemented management systems. Its production portfolio is focused primarily on manufacture of specific materials that are also used in healthcare, and require a detailed analysis of processes. The organization being provided a transitional period for its certified system to comply with the new requirements of the ISO 9001: 2015 standard based on ISO 9001: 2008, the company management decided to implement the requirements of ISO/DIS 45001 at this time, as they have a common structure resulting from the HLS structure. In this manner, the organization wants to gain time in case the issue of ISO 45001 differs from ISO/DIS 45001 in some of the requirements, and in case it is less challenging to adjust this OH&S management system accordingly.

3.1 The Description of the Selected Company

Ceit Biomechanical Engineering Company (hereinafter CBE) Ltd. was founded in 2010 as a spin-off of the parent company CEIT JSC and the Technical University of Košice (TUKE). The organization is a certified manufacturer of customized 3D printed medical devices. Its main activities are as follows:

- 3D print manufacture of individually customized titanium alloy implants (Ti64),
- treatment and processing of medical data

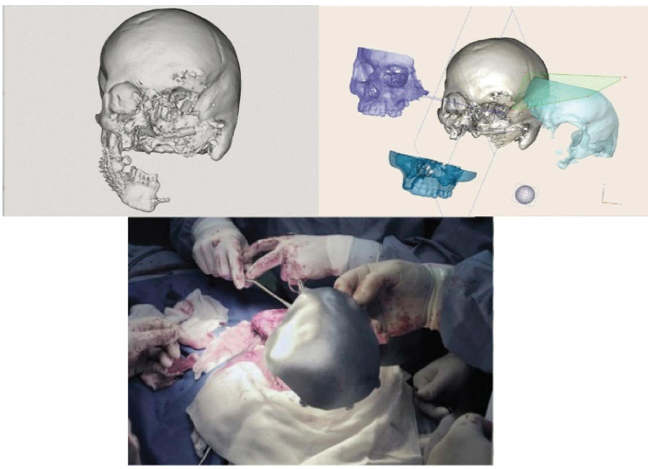


Fig. 3. Design and application of the implant to a patient

- manufacture of plastic and metal parts and prototypes made by 3D printing technology,
- 3D scanning, digitizing, reverse engineering, industrial metrology and diagnostics.

The manufacture of 3D printed implants is currently the core of its business activities. Around 25 implants, particularly of a cranial character, have been successfully implemented so far. The company has successfully designed and implemented a facial implant (Fig. 2).

As a part of the system security, the CBE organization has implemented three management systems, namely based on:

ISO 9001: 2008 for processes in the additive manufacturing, scanning and reverse engineering.

ISO 13485: 2003 for development, production and sale of medical devices.

OHSAS 18001 for digitized data processing and components made by additive manufacturing technology. Project Management.

3.2 Current Situation Analysis Related to ISO/DIS 45001

With the coming requirements of ISO/DIS 45001, the CBE decided to analyse the current status of the established OH&S management system in compliance with OHSAS 18001. The aim was to identify the diversity and propose measures to meet requirements under ISO/DIS 45001. The analysis was based on the ISO/DIS 45001 requirements structure. Following findings were identified there:

Context of the Organization (Chapter 4 of ISO/DIS 45001). CBE has identified its customers and suppliers. Identification of the other interested parties, including their requirements and expectations is missing. CBE is focused on 4 major processes:

1. Design and development of the product
2. Additive manufacture
3. Project preparation of production
4. Marketing and Sales

The current OH&S management system covers all processes in CBE. As regards to the key processes of the Design and Product Development and Additive Manufacturing, it is necessary to identify all the interested parties, including their (legislative) requirements and expectations. These are mainly regulatory authorities such as, Public Health Authority, Labour Inspectorate, and the like. In relation to OH&S management system, it mainly applies to institutions and authorities supervising compliance with the principles of OH&S management system.

Leadership and Working Participation (Chapter 5 of ISO/DIS 45001). CBE with its current OH&S management system meets the requirements following from ISO/DIS 45001 without further measures.

Planning (Chapter 6 of ISO/DIS 45001). The current OH&S management system includes identification of all the risks associated with the production. The specified risks are set out in the "Risk Analysis" document. A risk matrix method (type 5 $\times$ 5) is used for risk assessment. Based on the risk assessment, it was not necessary to take measures to minimize them. However, in the context of the new requirements, it will be necessary to update the risks identification and assessment even in relation to the context of the organization.

Support (Chapter 7 of ISO/DIS 45001). CBE has an elaborated, approved and publicly known OH&S policy. Its formulation provides a framework for setting OH&S objectives. The objectives are measurable, with a specified target date and responsibility. The OH&S policy and the resulting targets are regularly monitored and updated. In connection with the coming of new the ISO/DIS 45001 requirements, it will be necessary to update both documents.

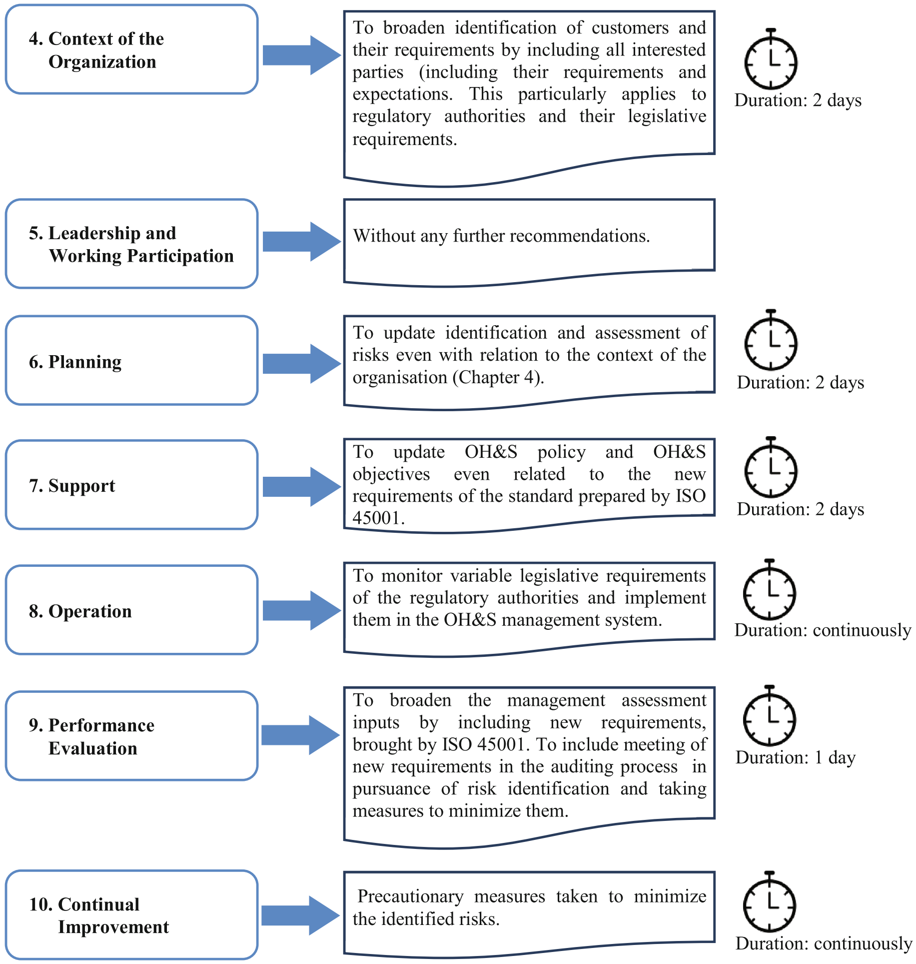
Operation (Chapter 8 of ISO/DIS 45001). CBE has to constantly monitor legal requirements of regulatory authorities and thus adapt the conditions of its processes. CBE has developed a procedure called "Trauma Plan". By its content, it complies with the requirements of ISO/DIS 45001 related to emergency preparedness.

Performance Evaluation (Chapter 9 ISO/DIS 45001). The CBE management periodically review the existing OH&S management system and ensures internal audits realization. Under the new requirements of ISO/DIS 45001, CBE will have to modify the content of management reviews, auditing process, and to focus on the new requirements under the Chapter 4, 6, or 10.

Continual Improvement (Chapter 10 ISO/DIS 45001). Preventive action (i.e. preventive measures) has been deleted from the requirements of ISO/DIS 45001. However, they have become a part of the Risk-Based Thinking (requirements in the chapter 6). The current customary precautions will become a part of risk management in the light of new requirements on the OH&S management system. With the risks identified as high, CBE will have to take (preventive) measures to minimize them. Measures resulting from remedial action do not change in the light of new requirements.

3.3 The Changes in Relation to the Requirements of ISO/DIS 45001

Based on the current status analysis done at CBE following from the ISO/DIS 45001 requirements, the following adjustments to the current OH&S management system were summarized (Fig. 3).



4 Conclusion

With the planned ISO 45001 standard, organizations will be expected to amend the existing certified OH&S management system. The aim of the paper was to show the actual amendments of the existing certified OH&S management system in the organization. The output of this article is to draft changes to be made for meeting the requirements of the upcoming ISO 45001 standard. CBE took this provisional step in order to shorten the transformation period of its management system when the requirements of ISO 45001 are finally released.

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Technological Systems in Compliance with Industry 4.0 Strategy" and VEGA Nr. 1/0150/15 Development of implementation methods and verification of integrated machinery safety, machinery systems and industrial technologies.

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Assessing the Safety Use of Tower Cranes on Construction Sites in Central Region of Ghana

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Abstract. Safe use of plants, equipment and moving machineries on construction sites are complex and delicate and these are determined by the immense number of brands and types of moving equipment options. Continuously Ghanaian operators get injured and even killed in plant associated accident in the construction industry. This is due to lack of occupational health and safety education to both the employer and their operatives. The construction industry is faced with problems of cost reduction, as accidents add to the cost of the construction, thereby reducing profit margins. The aim of this study is to investigate the safe use of plants on construction site. The objectives are to identify the causes of plant accidents on construction sites and to determine the level of enforcement of safety laws and rules. The study was conducted on finding out the problems associated with the safety of operators on construction sites in some selected sites in Central Region of Ghana. Convenient sampling technique method was used to select three DlKl construction companies and fifteen (15) operatives and three health and safety officers were selected. The research instrument that was used includes questionnaires, personal interviews and observations. The data was analyzed using the descriptive statistics that comprises mean and tables. The findings revealed that respondents with a mean score of 3.5 confirmed that competent persons are used to carry out the erection, dismantling and height alternation of tower cranes. However inadequate training and fatigue of operators are one of the main reasons causing unsafe practices of tower crane operations.

Keywords: Safety · Tower · Cranes · Construction · Sites

1 Introduction

[9] alluded that over 70% of industrial and construction site accidents are due to unsafe acts by operators of the machineries at those sites. Construction works are mostly dangerous and risky thus making safety and health care issues very important [20]. Due to the fact that accident rates in construction are high when compared to other

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industries, the construction and projects managers need to be fully prepared to deal with accidents when they occur. Accident statistics represent not only terrible human tragedies but also substantial economic lost. This is because accidents cause damage to plant equipment and the loss of productive work time until the normal site working rhythm and morale are restored. Accidents can also cause work disruption and reduce the work rate drastically [7].

The major causes of accidents are related to the unique nature of the industry, human behavior, difficult work site conditions, and poor safety management, which result in unsafe work methods, equipment and procedures. Emphasis needs to be placed on training and the utilization of comprehensive safety programs [8].

Plants, materials and manpower are the core resources on which all operations in the construction industry are successfully executed. This gives the indication that the absence of one part shall cause problems such as delay in operation, poor work amongst others. Plants usage therefore is of great benefit to the execution of every construction process. Transportation plants such as; cranes, chutes, vans, lorries, hoists and fork lifts have sped up construction works over the years by transporting materials from one place to the other in various directions. Excavation plants such as: bulldozers, skimmers, face shovels amongst others have provided builders the speed they needed to execute works in the shortest possible time.

1.1 Problem Statement

[2] reported that a man in his 30s died on the spot when a crane he and others were operating collapsed, at La, in Accra. The heavy weight lifting device mutilated the body of the operator, who was standing beneath the device when it collapsed. The other worker who survived the accident has been left traumatized. The crane, used in the construction of high rise buildings was being worked on when the accident occurred.

In 2002 two overhead cranes crashed on the ground killing an operator instantly. According to sources the two cranes were performing the normal lifting of heavy iron when they crashed to the ground [3].

Crane accidents [6] reported that A tower crane jib came crashing down onto abuilding it was working on in Charlotte Street, London. It is believed that that the crane lost its counterweight, although that has not been confirmed. The jib bent and dropped onto the facade of the building with the hook block landing on the bed of a delivery truck while the jib tip access platform was left dangling above the street.

In 2015 crane accidents recorded that seven men were killed in the Bihar region of India, after the boom of a small crawler crane came down on them.

A smaller barge carrying sand had apparently sunk and the crane was attempting to help when the boom luffing cables failed. The crane was clearly not in good working condition and had been the subject of complaints about its state [5].

1.2 Aim

The aim of this study is to investigate into the safety of cranes and their operators on construction sites.

1.3 Objectives of the Study

1. To identify the causes of crane-associated accidents on site.
2. To recommend the safety measures to be put in place to ensure crane accident-free policy.

1.4 Significance of the Study

The findings will promote safety awareness among crane operators and other construction workers on ensuring health and safety issue in the use of crane in Ghana.

2 Literature Review

Tower-crane work constitutes a critical component in the range of elements that make the work environment of construction sites essentially hazardous [12, 15].

The use of tower cranes, however, have their own safety problems as well; with the large-area work envelopes of tower cranes that commonly cover the entire site and the crane that often oversails beyond site boundaries, these safety problems have a major bearing on the overall work safety on site.

2.1 Operator

A crane operator is someone who uses the crane to transport various objects. There are many different types, makes, models and sizes of cranes, such as mobile cranes, tower cranes, boom trucks and self-erect tower cranes. Mobile cranes are used to do work a boom truck can't do – higher lifts, heavier loads, and lifts that need a longer reach.

[10] outlined the following duties of crane operators:

- Control equipment with levers, wheels, or foot pedals
- Move material according to a plan or schedule they receive from their superiors
- Set up and inspect material moving equipment
- Make minor repairs to their equipment
- Record the materials they have moved and where they moved them from and to

In warehouse environments, most crane operators use forklifts and conveyor belts. Automated sensors and tags are increasingly used to keep track of merchandise, allowing operators to work faster. In warehouses, operators usually work closely with hand material movers.

Many crane operators work for underground and surface mining companies as well. They help to dig or expose the mine, remove the earth and rock, and extract the ore and other mined materials. In construction, crane operators remove earth to clear space for buildings. Some work on a building site for the entire length of the construction project. For example, operators often help to construct high-rise buildings by transporting materials to workers far above ground level [16].

2.2 Slinger Signaller

The job of a slinger signaller is one of the most important jobs on a building site. It requires skill, diligence, and concentration, working alongside the lifting teams to provide safe direction and supervision to the crane operators.

The slinger signaller normally acts as the eyes and ears of the crane operator, who is likely to have an obstructed view of their surroundings. This obstructed view increases the risks involved with loading, lifting and generally operating the crane and so they need the slinger signaller to communicate via a series of hand signals to assist with maneuvers.

Their main responsibility is to ensure the safety of the operators, and any other workers or site visitors that could be at risk.

The standard hand signals used by slinger signallers are detailed in the Health and Safety Signs and Signals Regulations 1996, L64. They must be:

- Precise
- Clear
- Easy to make
- Easy to understand

In some situations these hand signals are not sufficient to maintain a safe working environment and more signals will need to be used. If this happens, the signaller must only use signals that have been pre-arranged with the operator (Health Safety Training, 2015).

2.3 Factors Affecting Safety in Tower Crane Operations

Negligence or Misjudgment of Participants in Tower Crane Operations. Most of the fatalities are due to carelessness, such as working too close to energized power lines, improper rigging, or lifting loads exceeding weight capacities of cranes [4, 14].

Inadequate Training. Workers who do not have sufficient training or knowledge about their jobs should not be expected to identify all unsafe conditions surrounding their work [1, 13]. Lack of safety training and formal education are significant risk factors for accidents [21, 20].

Sub-contracting Practices in Tower Crane Operation. Most construction contractors do not own and operate their tower cranes rather they rent them and operate them by in-house or contracted personnel [12]. According to [19] Multi-layered sub-contracting in tower crane operations bring salaries down for crane operators, resulting in chronic long working hours and mobility of crane operators which directly influences construction safety.

Pressure from Deadlines. A tight construction schedule is the most significant factor that hinders the implementation of construction site safety [11]. [19] noted that a job behind schedule can create an atmosphere of tension, tending to force people to work usually faster than normal, thus compromising safety. This gives rise to risks to the cranes, to nearby objects, to the rigging crew and to workers in the vicinity [14].

2.4 General Provisions in Using Tower Crane

According to [10] some of the general provisions in using tower cranes are stated as follows: The characteristics of the various machines available should be considered against the operating requirements and the surroundings in which the crane will operate before a particular type of crane is selected. Care should be taken in the assessment of wind loads both during operations and out of service. Account should also be taken of the effects of high structures on wind forces in the vicinity of the crane. The ground on which the tower crane stands should have adequate bearing capacity. Account should be taken of seasonal variations in ground conditions. Bases for tower cranes and tracks for rail-mounted tower cranes should be firm and level. Tower cranes should only operate on gradients within limits specified by the manufacturer. Tower cranes should only be erected at a safe distance from excavations and ditches. Tower cranes should be sited where there is clear space available for erection, operation and dismantling. As far as possible, cranes should be sited so that loads do not have to be handled over occupied premises, over public thoroughfares, other construction works and railways or near power cables. Where two or more tower cranes are sited in positions where their jibs could touch any part of the other crane, there should be direct means of communication between them and a distinct warning system operated from the cab so that one driver may alert the other to impending danger. When the tower crane is left unattended, loads should be removed from the hook, the hook raised, the power switched off and the boom brought to the horizontal. For longer periods or at times when adverse weather conditions are expected, out of service procedures should be followed. The main jib should be slewed to the side of the tower away from the wind, put into free slew and the crane immobilized. Devices should be provided to prevent loads being moved to a point where the corresponding safe working load of the crane would be exceeded. Name boards or other items liable to catch the wind should not be mounted on a tower crane other than in accordance with the manufacturers' instructions.

3 Research Methodology

Convenient sampling technique was used to select five DlKl construction companies and twenty (20) respondents comprising (5) operatives; (5) slinger signalers; (5) health and safety officers and (5) contractors were selected. The research instrument used includes questionnaires, personal interviews and observations. A five-point Likert scale was adopted in the questionnaire. The questionnaires were sent to construction personnel who are handling tower crane related operations, including crane operators, slinger signalers, safety officers and contractors. The data was analyzed using the descriptive statistics that comprises mean and tables (Table 1).

Table 1. Reported cases of accidents of tower cranes from 2002 to 2015

Date	Location	Accident/incident
10/10/2002	Tema Steel Works Factory	Two overhead cranes crashed on the ground killing one operator instantly. According to sources the two cranes were performing the normal lifting of heavy iron when they crashed to the ground
9/10/2013	La, Accra	A man in his 30 s died on the spot when a crane he and others were working on collapsed, at La, in Accra. The heavy weight lifting device mutilated the body of the operator, who was standing beneath the device when it collapsed. Another operator who survived the collapse of the crane has been left traumatized

4 Findings and Discussion

Table 2 reveals that most of the respondents were able to identify crane operators, having a mean score of 4.35. The respondents revealed that crane operators often work without a clear and unrestricted view of load carried, point of loading and vicinity of cranes. This highlights a rise in danger of tower crane operations with a mean score of 1.65.

All respondents agreed that they are capable of handling slinging works of tower crane operations on hearing, eyesight and reflexes, and they are agile and have the physical strength to handle lifting works.

[19] concluded that An effective communication between crane operators and other personnel is essential for safe crane operations. Failure to implement an effective communication between crane operators and other personnel will lead to unsafe crane operations, and may contribute to injuries to people from dropped loads and collision with other plants and structures. Radio/tele-communication signals and hand signals are the major communication methods between crane operators and other personnel.

Table 3 one observes that a greater number of the respondents having a men score of 4.25 fully understand procedures of erecting and dismantling tower cranes and alternating height of tower cranes however most of the respondents indicated that the erection and dismantling of tower cranes and alternate height of tower cranes in compliance with manufacturers' instructions in such procedures are not followed giving a mean score of 2.85. Also most of the respondents acknowledge that before the erection, dismantling and height alternation operations, a competent examiner carries out test or examination meanwhile after the erection, dismantling and height alternation operations, a competent examiner do not always carry out test or examination. The respondents indicated that they have not been provided formal training by their employers. They normally exercise their skills via on-job training.

Table 2. Responsibilities of crane operators and signalers

Item	Factor Or Activity Description	Ratings based on the respondents experience over crane operations Least Influential ← → Most Influential					Scores	
		1	2	3	4	5	Total	Mean
1	You can be easily identify crane operators	0(0)	0 (0)	3(9)	7(28)	10(5 0)	87	4.35
2	You understand signalers' responsibility	4 (4)	3(6)	4(12)	4(16)	5(25)	63	3.15
3	An unobstructed field of vision is provid	2 (2)	2 (4)	3 (9)	8(32)	5(25)	72	3.60
4	You are capable of handling slinging works of tower crane operations, particular to hearing	1(1)	3(6)	9(27)	5(20)	2(10)	64	3.20
5	You are capable of handling slinging works of tower crane operations, particular to eyesight	1 (1)	4 (8)	3(9)	6(24)	6(30)	72	3.60
6	You are capable to handle slinging works of tower crane operations, particular to reflexes	0(0)	5(10)	4(12)	6 (24)	5(25)	71	3.55
7	You are agile to handle lift	3 (3)	4(8)	8(24)	2(8)	3(15)	58	2.90
8	You have the physique to handle	7 (7)	8(16)	0(0)	3(12)	5(25)	60	3.00
9	You are capable of directing movement of cranes and loads for ensuring safety of personnel and plants	12 (12)	2 (4)	1(3)	3(12)	2(10)	41	2.05
10	You fully understand radio/tele-communication signals among crew members	13 (13)	3 (6)	2(6)	2(8)	0 (0)	33	1.65
11	You are familiar with signals for crane directions	11 (13)	3 (6)	2(6)	2(8)	2(10)	43	2.15

Usually it is common to employ sub-contractors to provide services with operatives and tools for erecting, dismantling and alternating height tower cranes. It is because most main contractors do not have their own tower cranes. They may not have workers who are familiar with the required procedures. The use of sub-contractors for the erection, dismantle and height alternation of tower crane operations may do not also help in the provision of training related to tower crane operations.

The respondents with a mean score of 3.5 noted that competent persons are used to carry out the erection, dismantling and height alternation of tower cranes. Most of the respondents agreed that for the erection, dismantling and height alternation operations, a roped-off area is provided which has been clear of other personnel who are not involved; it had mean score of 3.2.

Table 3. Safety of erection and dismantle of tower cranes

Item	Factor Or Activity Description	Ratings based on the respondents experience over crane operations Least Influential ← → Most Influential					Scores	
		1	2	3	4	5	Total	Mean
1	You fully understand procedures of erecting and dismantling tower cranes and alternating height of tower cranes	0(0)	0 (0)	3 (9)	9(36)	8(40)	85	4.25
2	You fully understand manufactures' instructions in erecting and dismantling tower cranes and alternating height of tower cranes	1 (1)	2(2)	4(12)	5(20)	7(35)	70	3.50
3	You erect and dismantle tower cranes and alternate height of tower cranes in compliance with manufacturers' instructions in such procedures	6 (6)	4 (8)	2 (6)	3(12)	5(25)	57	2.85
4	You carry out erection, dismantle and height alternation of tower cranes under supervision of a competent person	2(2)	3(6)	4(12)	5(20)	6(30)	70	3.50
5	For the erection, dismantling and height alternation operations, a roped-off area is provided which is clear of other personnel who are not involved	3 (3)	4 (8)	3 (9)	6(24)	4(20)	64	3.20
6	Before the erection, dismantling and height alternation operations, a competent examiner carries out test or examination	2(2)	5(10)	3 (9)	6(24)	4(20)	65	3.25
7	After the erection, dismantling and height alternation operations, a competent examiner carries out test or examination	3 (3)	4(8)	8(24)	2(8)	3(15)	58	2.90

Procedures and Precautions for Tower Crane Operations. From Table 4: a greater number of the respondents with a mean score of 3.90 noted that at the beginning of each shift or working day, competent operators or competent persons carry out routine checks, however a check list is not used in each routine check and inspection this had a mean score of 2.70. [19] admitted that preventive maintenance can effectively eliminate accidents caused by defective parts of tower cranes. Routine checks and thorough inspection are precedent to preventive maintenance. Therefore, inspection is one of the key precautions to prevent tower crane accidents. However, sometimes, tower cranes are rush to move to another sites, some tower crane providers or owners may omit checking and maintenance of tower cranes. According to the respondents, tower crane components, such as slings, hooks and masts have been periodically checked and tested by competent examiners.

Table 4. Procedures and precautions for tower crane operations

Item	Factor Or Activity Description	Ratings based on the respondents experience over crane operations Least Influential ← → Most Influential					Scores	
		1	2	3	4	5	Total	Mean
1	At the beginning of each shift or working day, competent operators or competent persons carry out routine checks	0(0)	2(4)	5(15)	6(24)	7(35)	78	3.90
2	Apart from routine checks, at least once a week, a full inspection of tower cranes is carried out by competent persons	2(2)	5(10)	3(9)	4(16)	6(30)	67	3.35
3	You fully understand items to be inspected	0(0)	0(0)	4(12)	7(28)	9(45)	85	4.25
4	A check list is used in each routine check and inspection	6(6)	4(8)	3(9)	4(16)	3(15)	54	2.70

5 Conclusion

The firms the researcher visited do organize, train and educate their operatives on health and safety programs, but the operatives do not put into practice the knowledge acquired from the health and safety programs organized for them. The firms have safety officers to educate operatives on the risk involved in their work and also to show commitment to the implementation of the safety but the officers are not punctual. The firms were not linked to any medical personnel, clinic or hospital in case of injuries sustained.

Blind lift is the major cause for crane-associated accidents followed by obstacles and congested site, power lines, cab ergonomics, sight distance and angel, and overlapping cranes. Almost all the crane operators get so excited when performing lifting's, they therefore lift before considering the exact location in most cases hence exposing both the operators and the employees in the area of operation to safety hazards and probable crane associated accidents on the sites. The measure put in place in order to maintain and improve the safety of cranes operator is to implement Safety policies. But though the firms have safety policies, they were not effective.

5.1 Recommendation

These recommendations are based on the findings and conclusion drawn in the study.

The firms should make sure they organize, train and educate operators the need to execute their task ensuring accident free activity. The training for different duties in tower crane operations should be strengthened, particular in rigging operations as well as erecting, dismantling, climbing and alternating height of tower cranes. In addition, training for new entrants in the field should be strengthened. The firms should put measures in place in other to ensure the operators of the crane carry out lifting's as required of them as professionals. The firms should make it a point that their policies are implemented and working effectively, and also the entire operatives on the site are aware with the safety policies of the firms and it should be written in a clear and simple language so that it is easily understood.

It can consider expanding certification mechanism from crane operators to other relevant parties in tower crane operations, such as erectors, signalers, foremen and coordinators.

Proper checks, inspections and examination of tower crane should be carried out by a recognize company mandated in ensuring standard. The companies should make sure they provide enough safety equipment's to the employees and also set a site safety committee to make adequate supervision on the employees in wearing and using the safety equipment when it is due to be used for works.

It is well known fact that, the promotion of safety in the construction industry plays a vital role in providing a guide to employers and the government as well.

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Study on Error-Cognition Mechanism of Task Interface in Complex Information System

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Abstract. With the rapid development of computer technology and information control theory, information systems become more complex and intelligent. Transportation hub monitoring system, nuclear power control system, environmental monitoring system, and other large systems have evolved from the traditional control mode to digital control mode. Because digital information interaction interfaces are characterized by the large quantity of information and complicated information relationships, operators may enter the complex cognition and lead to task failures and even serious system failures or major accidents due to operators' slipping, misreading, misjudgment, late feedback, and other cognitive difficulties. It is urgent to obtain the rational design way of dynamic and digital information in the interaction interface. This paper aims to analyze interaction mechanism between error and cognition and explore the physiological reaction mechanism for error factors of information interaction interface during the visual cognition from the perspective of the cause of task failures, error factors. The project results can provide theoretical supports for the rational design of digital information interface and guarantee the full performance and accurate implementation of large systems.

Keywords: Information interaction · Human-computer interface · Error factors · Visual cognition · Error-cognition model

1 Introduction

With the rapid developments of computer technology and information technology, human-machine interfaces of great intelligent manufacture equipment, nuclear power plants, even aircrafts, ships, battlefield command systems, and other digital information systems have evolved from the traditional control mode to digital control mode with information interaction interface. Compared with the conventional analog control which is generally monitoring and operating system, digital control shifts the role of operators from manual controlers to regulators and decision-makers, which increases the process of operator's visual cognition and needs a set of cognitive behaviors perform the task (as shown in Fig. 1). Because digital information interaction interfaces are characterized

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by the large quantity of information and complex information relationships, an operator may enter the complex cognition and lead to task failure, even serious system failures and major accidents due to operation errors, misreading, misjudgment, late feedback, and other cognitive difficulties.

Fig. 1. Analog control of an intelligent system (Left) and displays of digital control (Right)

Information interface is the major resource for operators to learn about the tasks, which as well as threat and security state information. Operators must grasp distinct, real and complete information of combat situation, so that to have the initiative to the battlefield in hands. Thus, it is clear that the display of information about the interaction system is extremely significant. The information display regarding to automatic combat identification system has been studied [1]. This paper discussed how these two groups of forms, uniforms and helmets, be presented to conduct the identification of combat information as well as the information analysis with combination of information reliability. After obtaining the reliable simulated data, there was found that the display formats of mesh chart and integrated data are more adaptive for combat information identification. The researchers have studied the identification performances of the colors, positions and shapes of different symbols and texts, and have obtained a series of valuable results [2–4]. The layout design of fighter radar situation-interface has been evaluated experimentally and has been analyzed through an objective evaluation technology of eye's tracker [5, 6]. They also have selected a special scheme of rational layout optimization through the evaluation by eye's moving data indexes. The researchers simulated the general operation sequence of enemy attack task in avionics system to conduct interface design [7]. The researchers have studied the influence of complex digital interfaces on color and shape codes to explore the identification performances under different time pressures [9].

Currently, few people in the field of visual information interface have started researches in the base of error factors, especially applied to aviation, military and other complex systems which are displayed by multilevel subsystems, whose error factors are concentrated in visual information display of executive monitoring, search and other tasks and its cognition mechanism of errors is an important hitting-point for improving interface design as well as the key for reducing cognition difficulties. Wu [8, 10, 11], proposed a new interface design method by introducing error factors and established the error-cognition stratification model for digital information task interfaces.

2 Objective

Digital information task interface is characterized by transforming systematic abstract information into user interfacial elements which are easy to identify and understand. Graphical user interface conveys several elements, including character, text, image, icon, colour, dimension, and so on. When the information displayed is complex, only the reasonable navigation design and structure design of information hierarchy can reach the rationality of information interaction. Thus, the design problem of information interaction interface has evolved into a hot spot and focus problem which was concerned mutually by researchers in human-factors engineering, automatic control, cognitive psychology, systematic science, design science and other disciplines. Then, whether the design factors of information interaction interface could begin with the source of task failures– error factors? The key point lies in how to understand correctly the interaction mechanism between 'error and cognitive', then, can we propose a reasonable design strategy for the optimization of visual information interface.

3 Method

This paper studies error factors of information interface in human-computer interaction based on visual cognition theory. A feasible error-cognition model is established to solve some design problems which result in serious failures in information recognition and analysis, and even in operation and execution processes. Nielsen [12] and Shryane [13] proposed the availability interface design method to reduce human error probability (HEP). Yoshikawa [14] studied human error probability (HEP) through user evaluation model. And Krokos and Baker [15] also proposed interface cognition error classification method. Maxion [16] improved operation interface dependability through mitigation of human error (External Subgoal Support). Based on Rasmussen, Norman, Reason and other error types as well as the HERA and CREAM failure identification models, we performed classification and cognitive characterization for error factors according to information search, information recognition, information identification, information selection and judgment as well as the decision-making process and obtained the comprehensive error-cognition model for digital information interface. Based on the behavioral data and the physiological data derived from eye movement tracking, the misperception factors leading to users' information omission/misjudgment are detected.

4 Model

4.1 Operator's Cognitive Behavior Model

As shown in Fig. 2, based on the information central processing of interaction task interface, forming the cognitive process from information input to information feedback. During the process, we need to analyze the operator's cognitive behaviors based on the execution of the task. Information search, information recognition, information identification, information selection and judgment as well as the decision-making process are just operator's cognitive behaviors of information observation, explanation, planning and execution during the process of executing the task. Thus, this paper will continue to explore the information process of complex interaction task interface in depth.

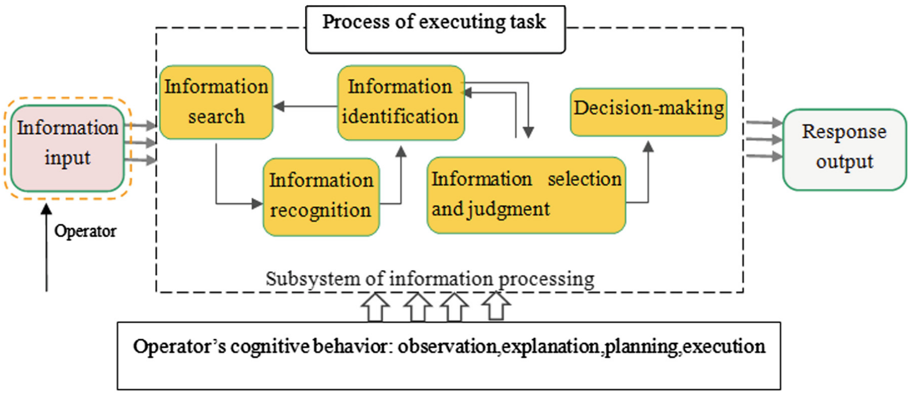

Fig. 2. Central processing of information of interaction task interface

4.2 Analytical Model of Cognitive Error Recognition

We can combine extended operator's cognitive behavior model with corresponding analytical model of error recognition, and further recognize the cognitive error of the interfacial task. Embrey, Altman, and Swain, et al. tried to use the basic behaviour component of the operator to describe the behavior of the operator with "error" event characteristics from the view of traditional human factors; PHEA and HRMS et al. established the analysis model of human factor from the perspective of cognitive psychology. The technology of HERA proposed by Kirwan [17], which integrates several methods and enables the analysis results to be tested each other, is reliable relatively. Thus, this paper will apply error recognition framework to analyze the cognitive error recognition of information search, recognition, judgment and selection, as well as decision-making. According to the process of operator's cognitive behavior, operator's task (as shown in Fig. 3), task function as well as task steps and structure are unfolded, corresponding with the analytical opinion of human reliability, which includes task analysis, objection analysis, operation analysis, planning analysis, error analysis, psychological error mechanism analysis, performance shaping factor analysis as well as human error identification in systems tool analysis.

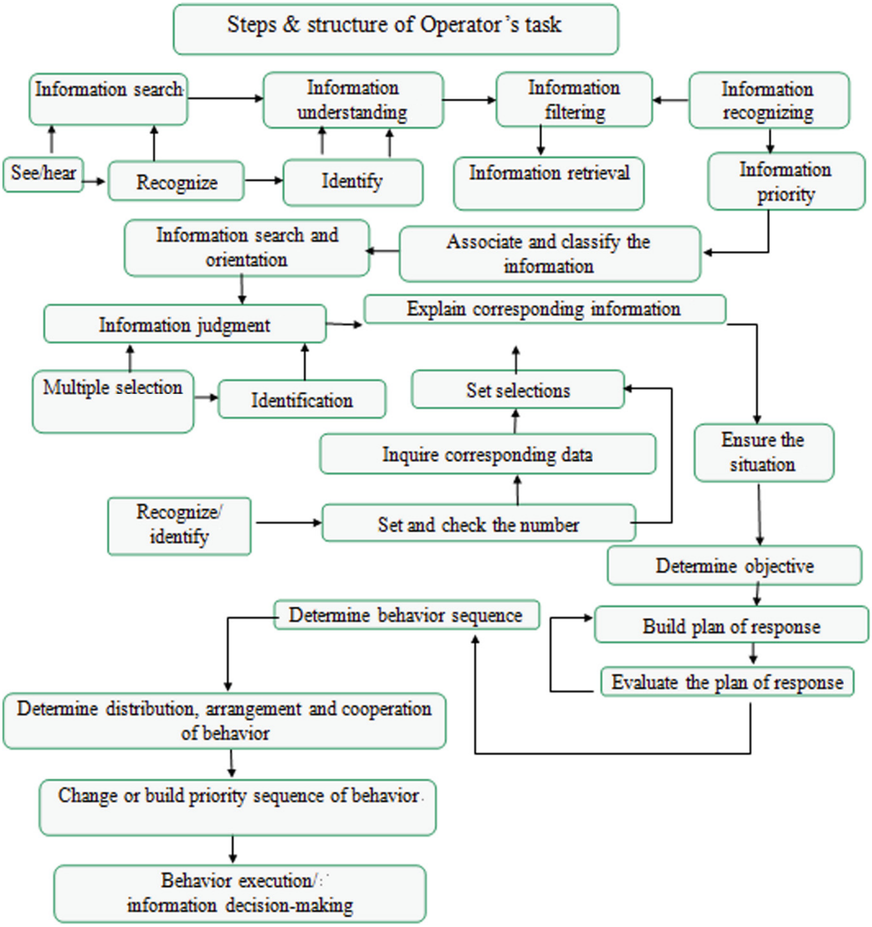

Fig. 3. Error recognition analytical model of operator's cognitive behavior

4.3 Error Recognition Analytical Model

Error factors in cognitive behavior process are implicit, and manifest as explicit behavior errors, such as incorrect execution and selection, so what left to be resolved is cognitive analysis of implicit error factors. To further characterize the error factors of information interface, according to the interfacial task in complex system environment, operator need perform five following cognitive behaviors: search, recognition, identification, judgment and selection, decision-making. Keep the information display format of different task corresponding with cognitive behavior or possible error factors, then, we can characterize the errors. As shown Fig. 4, it aims to analyze interaction mechanism between error and cognition and explore the physiological reaction mechanism for error factors of information interaction interface

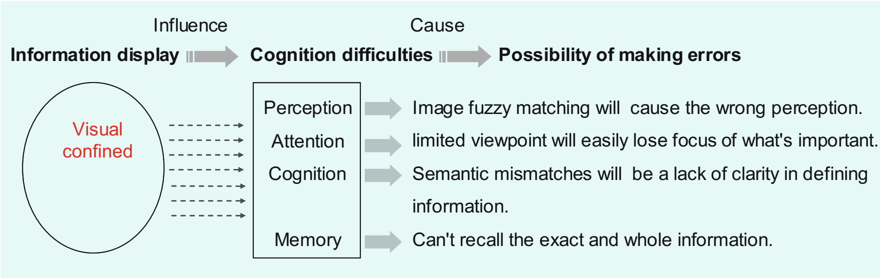

Fig. 4. Influences of visual confined on perception and possibility of making errors

4.4 Eye-Tracking Experimental Model

In order to analyze different information features in a information interaction interface, such as information layout, information display, task type and potential problems in information extraction, the experimental paradigm of feature analysis and eye tracking technology are applied to study the factors involved during visual searches for information. The experiment focuses on the attention processing feature of human eyes when searching for information, based on the condition that the task monitoring interface displays digital information features. It is designed to check if there is any difference in eye movement indexes for different tasks and information areas, and to explore the relative differences between different searches in different information areas, as shown in Fig. 5.

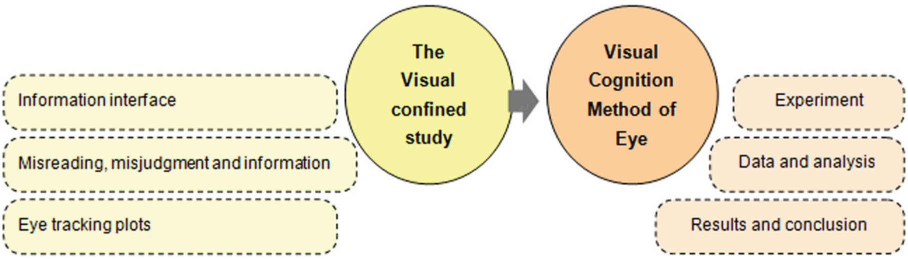

Fig. 5. Error recognition analytical model of operator's cognitive behavior

As shown in Fig. 6, firstly, extract the error factors of visual interface design factors to be analyzed; Then, select relevant cognitive model (theory) and psychological experimental paradigm and apply the error factors as independent variables to design the experiment; Lastly, employ the method combining reaction time and eye tracking to carry out the experiment.

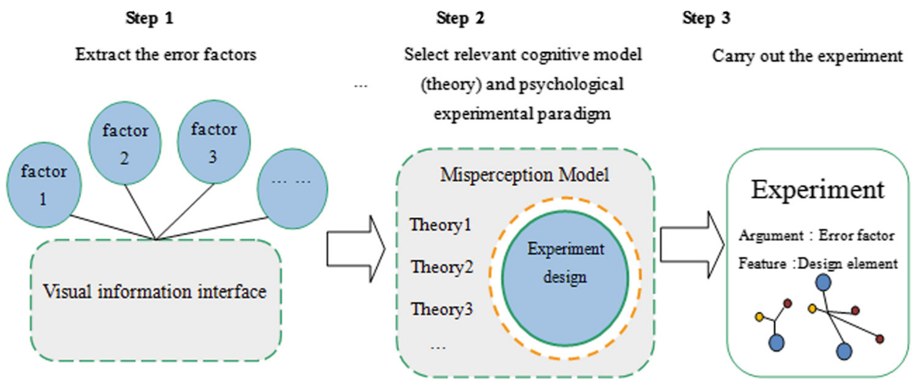

Fig. 6. Error recognition analytical model of operator's cognitive behavior

5 Application

5.1 Experiment Design

The paper simulated the radar situation-interface of complex system. The nested cognitive experiment of reaction time and eye movement tracking was conducted. The experiment 1 focuses on the attention processing feature of human eyes when searching for information, based on the condition that the task monitoring interface displays complex information features. It is designed to check if there is any difference in eye movement indexes for different tasks and information areas, and to explore the relative differences between different searches in different information areas. This experiment uses a real task monitoring interface as the visual search material for eye tracking, and displays the same information interface when subjects are undergoing different tasks. This experiment was conducted by adopting two-factor (4 tasks × 9 areas) within the experiment design. Specifically, the tasks are divided into task 1, task 2, task 3 and an independent variable for where no task is set for the subject, based on the main tasks of an operator of the monitoring process.

The experiment 2 factors causing error problems like information omission and misjudgment in the radar situation interface are analyzed. Based on the behavioral data and the physiological data derived from eye movement tracking, the misperception factors leading to users' information omission/misjudgment are detected.

5.2 Experiment Results and Discussion

Eye movement data indexes in nine areas of the task monitoring interface have been analyzed for each task based on a division of the different task monitoring areas. The experiment 1 demonstrate that the search path followed by subjects on the task monitoring interface show significantly different subject reaction times and eye movements when undergoing each different task, as the search path is influenced by task-driven cognitive information processing and information search time. Fixation duration,

duration count and visit count also show significant differences in each different monitor area; therefore information features distributed in the radar sub-interface can be easily captured, which have been proven to be related to task-driven automatic capture. Information position and features such as colors, shapes and sizes have a significant impact on visual searches as they can easily cause problems with information omission, misreading and misjudgment, missing/ignoring data etc. when undergoing each different task (as shown Fig. 7). The paper concludes that monitoring tasks and the individual information features within in an interface have a great influence on the visual search, which will guide further research on design of information features in task monitoring interfaces.

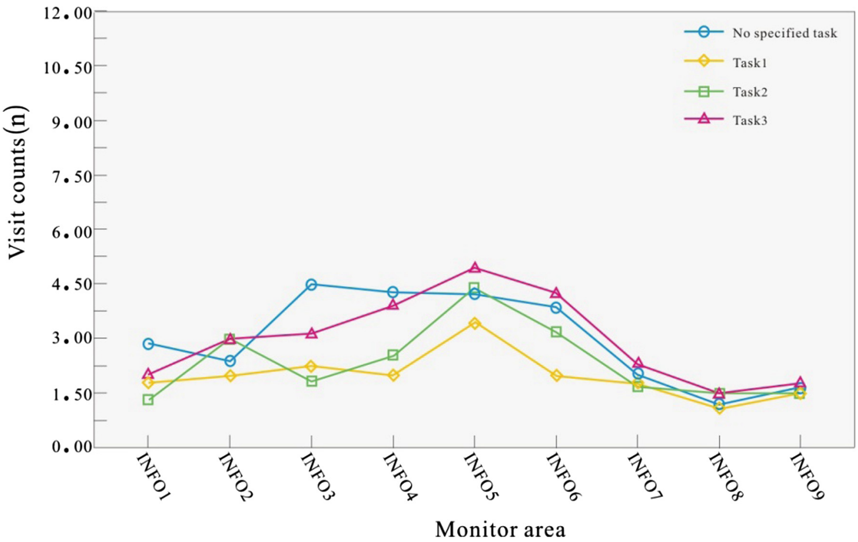

Fig. 7. Visit counts in difference monitor area

(ANOVA of the monitor area when undergoing different tasks indicates that the main effect of monitor areas ($F = 9.033$, $P = 0.004$, $p < 0.01$) reaches a statistically significant level).

The experiment 2 results showed that, (1) Both interval size and vision position impose a significant influence on the visual cognition of target search. The interval should not be too large for target search in the situation interface, otherwise it may result in long reaction time and omission and misjudgment. (2) During the target search in the upper vision, lower vision and peripheral vision, the reaction time and the error rate present significant changes, and the reaction time of peripheral vision achieves the longest. The vision position also exerts a remarkable influence on the first saccade latency. The fixation duration and fixation point number display obvious changes, and the mean fixation duration of the lower vision is the longest while its fixation point number is the smallest, which is apt to cause misjudgment and omission of information. The variance analysis on reaction times showed that, the main effect of intervals of upper visual positions ($F = 14.416$, $P = 0.012$, $p < 0.05$) and that of peripheral visual positions ($F = 6.990$, $P = 0.00103$, $p < 0.05$) both reached remarkable levels. The variance analysis on error rates showed that, the main effect of intervals of upper visual positions ($F = 2.380$, $P = 0.013$, $p < 0.05$) and that of peripheral visual positions ($F = 9.308$, $P = 0.014$, $p < 0.05$) reached remarkable levels. (3) Eye movement plots can effectively reflect the process of information search, and the gaze plot and the heat point map can present the relevant factors of information omission. And the conclusion reached can be used as reference for the information design and layout of the situation interface of future complex system, so as to effectively improve the misperception problems like omission and misjudgment in the target search process.

6 Conclusion

(1) This paper aims to analyze interaction mechanism between error and cognition and explore the physiological reaction mechanism for error factors of information interaction interface during visual cognition from the perspective of the cause of task failures, error factors.
(2) The design problems, resulting in serious failures in information recognition and analysis, and even in operation and execution processes, could begin with error factors.
(3) A feasible error-cognition model is established to solve some design problems which result in serious failures in information recognition and analysis, and even in operation and execution processes.
(4) It carries out an experimental study on eye movement tracking when performing different visual searching tasks on a task monitoring interface, from the perspective of psychometrics. Behavior and physiological reaction data have been obtained through experiments.

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The Design of Alarm Systems and Alarm Management - An Empirical Investigation from an Ergonomic Perspective

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Abstract. This paper reports results of a study dealing with the ergonomic design quality of the alarm system and alarm management in 15 process control systems from different sectors of industrial production. Based on available guidelines and ergonomic evidence, a checklist was designed and applied to these systems to test for compliance with these guidelines. The results show that there is a great deal of non-compliance with the requirements, leading to severe impairments of process safety. The main areas of design deficiencies have been found in the lack of prioritization of alarms, a lack of action guides in the presentation of alarms, lack of continuous improvement of the alarm system, a lack of systematic training concepts and training of alarm handling. Feeding back the results to the companies involved clearly showed that they were looking for help in dealing with these problems.

Keywords: Alarm system · Alarm management · Checklist · Process control · Process safety

1 Introduction

Investigations into incidents, e.g. in the nuclear power plant Three Mile Island (Harrisburg, 1979), in the Texaco (Milford Haven, 1994) or BP (Texas City, 2005) refineries, as well as on the Deepwater Horizon oil rig (Gulf of Mexico, 2010), demonstrate the impact that inappropriate design and management of alarm systems can have for employees, companies, the environment and the public. The investigation reports indicate that – in addition to technical and organizational deficiencies – poorly designed and managed alarm systems were jointly and to a substantial amount responsible for these events and their serious consequences. High alarm rates, poor prioritization of alarms, non-ergonomic and inappropriate design of displays, non-response of alarms and the lack of systematic training and training concepts for control room operators in dealing with critical situations were named, among others, as – at least contributing – causes [e.g. 1–3].

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Based on lessons learnt from such experiences in the field (best practice) but also on research into safety and human factors, over the past decades, a series of international and national standards and guidelines with recommendations for an ergonomic design of alarm systems and alarm management have been developed [e.g. 4–8] and numerous publications with relevant findings and recommendations have been published [e.g. 9–11].

However, it is unclear to what extent these design requirements and recommendations have been implemented into operational practice in different branches of process industries, at least in Germany. Therefore, a research project has been conducted to address the following questions:

1. How can the ergonomic design quality of alarm systems and alarm management be easily, consistently and reliably assessed? [not dealt with in this paper]
2. What is the current quality of the design of alarm systems in industrial control rooms from an ergonomic point of view?
3. What are important ergonomic recommendations to further improve existing and future alarm systems and alarm management?

This paper will concentrate on design aspects, while another paper by these authors [12] concentrates on the methodological aspects of these problems.

2 Method

2.1 Checklist Development

For the intended purpose of the present project, a computerized checklist based on a feasibility study [13, 14] has been further developed in order

1. to analyze and evaluate the design quality of alarm systems and alarm management in different control rooms and within various sectors of industry,
2. to gain some insight into the implementation of design requirements in this field and
3. to derive hints for potential improvements or needs for action in implementing (normative) design requirements and recommendations where appropriate.

Based on design requirements extracted from relevant literature, guidelines and normative provisions [e.g. 2, 5–8, 15, 16] an extended knowledge base has been accumulated, in which the recommendations were collated, summarized and structured into thematic areas, such as design of alarm systems (e.g. prioritization), design of operator adapted requirements (e.g. operator performance limits) and design of alarm management (e.g. performance monitoring and improvements).

A sample of prominent, relevant and substantially important characteristics from the knowledge base was selected by expert reviewers in a multi-staged process, transferred into questions which were supplemented by examples and notes. A complete evaluation of all potentially relevant characteristics for an alarm system is not possible due to technical, temporal and financial reasons.

Answer categories used in the checklist were either pass/fail decisions (yes/no) or – as in most cases – decisions for traffic light categories, with ‘Green’ representing good design condition, requirements completely fulfilled, ‘Yellow’ standing for basically OK, but better solutions would be conceivable, while ‘Red’ representing an unsatisfactory design solution, asking for improvement.

The computer-based checklist was implemented as an offline version using a portable computer and an online version provided by a browser via internet. The computerized version of the checklist offers a number of advantages, such as (1) incorporation of jump functions in order to provide the assessor with only those questions that are relevant to the system to be assessed, (2) all questions were defined as mandatory questions, so that no question remains unanswered, (3) hyperlinks for explaining terms and concepts can be integrated, (4) raters’ comments are easily readable and (5) the data is immediately available after completion of the assessment in a form that allows a direct import into common statistics programs, to name but a few.

2.2 Checklist Suitability

The checklist was tested in a multi-step procedure. As a first step, the draft version of the checklist was reviewed by experts in ergonomics and human factors for its suitability for the intended purpose, resulting in a final draft version with several modifications, for instance items were added, modified by rephrasing of questions and explanations or supplementing examples or deleted.

Afterwards, this final draft of the checklist was tested for usability in operational use by a senior member of staff from a chemical company and by two human factors and ergonomics experts (HF/E experts). The company expert was asked to go through the checklist, read all the items of the checklist (including explanations and examples) carefully and write comments if something was unclear, ambiguous, difficult to understand etc. The two HF/E experts were asked to apply the checklist to an alarm system and alarm management in a typical control room within the chemical industry under realistic operation and investigation conditions and comment needs for amendments regarding structure, content and checklist design.

The comments or suggestions made by both parties and the experience gained from these two checks were appraised and subsequently discussed by the above mentioned expert group, which resulted in a final adjustment of the checklist.

The final version of the checklist for the present study contains 148 items, arranged in the following design areas:

1. Alarm generation/alerting
2. Alarm presentation
3. Alarm prioritization
4. Alarm system functionalities and technical measures
5. Consideration of operator performance limits
6. Action guidelines and system interactions
7. Control and feedback
8. Alarm culture and alarm philosophy
9. Continuous improvement
10. Documentation
11. Training

2.3 Checklist Application

The final version of the checklist was applied within 14 control rooms at 12 medium-sized or large companies throughout Germany, where 15 systems (including the alarm management) were analyzed in detail. Participating companies were from three industrial sectors: electrical power generation and distribution, chemical industry and food industry; but mainly from the first two sectors. The assessed systems were from eight different manufacturers for process control engineering. These process control systems were implemented between the 1980s and 2014/15, almost all of them were (regularly) updated.

Each system was evaluated with the aid of the checklist by two HF/E experts at least and – where possible – by one or two experienced practitioners from the company such as technicians, system engineers, safety experts etc. This study design, for example, allows a comparison between individual assessors and assessor groups [12].

Observation, visual inspection, interviews with control room operators and supervisors, physical measurements and document analyses were used as methods of data collection.

The HF/E experts conducted their assessments independently on two separate days. Every assessment lasted between 7 and 10 h per working place, varied according to the complexity of the process under control, the process control system under investigation, the type and extent of the alarm management activities and the events specific to the days of assessment and usually a part of a second shift was included. In contrast to the HF/E experts, the experienced practitioners did not have to carry out their assessment on one day. They could save their results at any time and complete the checklist at a later date. Therefore, no information is available about the time required for investigations carried out by the engineering staff.

Investigations have been completed by the HF/E experts, but are still ongoing as regards the experienced practitioners from the participating companies. In particular, 30 assessments done by the two HF/E experts and 22 assessments done by experienced practitioners are available at present, i.e. eight ratings by practitioners are still missing. Thus, only results by HF/E experts will be reported in this paper.

2.4 Statistical Analysis

Only a first descriptive analysis of data has been carried out so far. Data analyses were conducted, inter alia, with a view to estimating differences in compliance with design requirements according to (1) total compliance with requirements, (2) branches of industry, (3) individual workstations, (4) design areas and (5) specific requirements (individual items) by performing separate analyses of conformance with these requirements, based on calculating and accumulating percentages of compliance with individual requirements, e.g. with items and aspects under consideration.

3 Results

3.1 Compliance in General

Descriptive analyses of compliance with all requirements as well as at checklist design area level or item level indicate substantial differences in the design quality of the alarm system and the alarm management across all workstations analyzed. The results show that none of the systems under investigation fulfilled all design recommendations derived from the relevant literature, guidelines or standards, as would have been expected, given the diversity of systems under investigation (see Fig. 1). All analyzed objects have design deficiencies and there is partly considerable room and necessity for improvement.

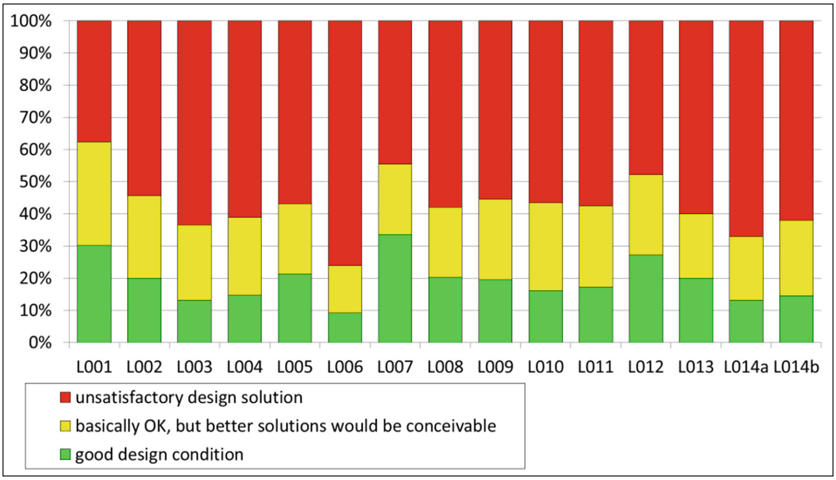

Fig. 1. Compliance across systems under investigation

Regarding single compliance rates, only about 9–34% good design condition and about 15–32% acceptable, but improvable condition over all requirements leaves about 38–76% of non-compliance with normative requirements based on relevant guidelines or the available evidence, so that even for the system with the best compliance remains a degree of non-compliance of 38%, which would argue for necessary improvements in the design and management of the alarm systems under consideration.

Comparing sectors of industry showed less compliance in the food industry than in the other two, with only slight differences between the chemical and the power industries.

Comparing design areas, it becomes obvious that prioritization of alarms, consideration of operator limits and providing action guidance show most deficiencies in the technical design of the system (N.B. the sum of items per design area differs, see Fig. 2), while continuous improvement and (especially) systematic training and training concepts for alarm handling represent the areas of the greatest design deficiencies on the organizational level.

3.2 (Non-)compliance with Specific Requirements

Going down to the level of individual items (see Fig. 2) it can be seen that – across all systems under investigation – a few items achieve acceptable compliance rates, whereas others achieve high degrees of non-compliance (the higher the value, the higher the degree of non-compliance), e.g. from the areas of training (TR), alarm prioritization (PR), action guidelines and system interactions (HA) and continuous improvement (KV), as reported above. In general, however, there is a large variation in compliance with individual items.

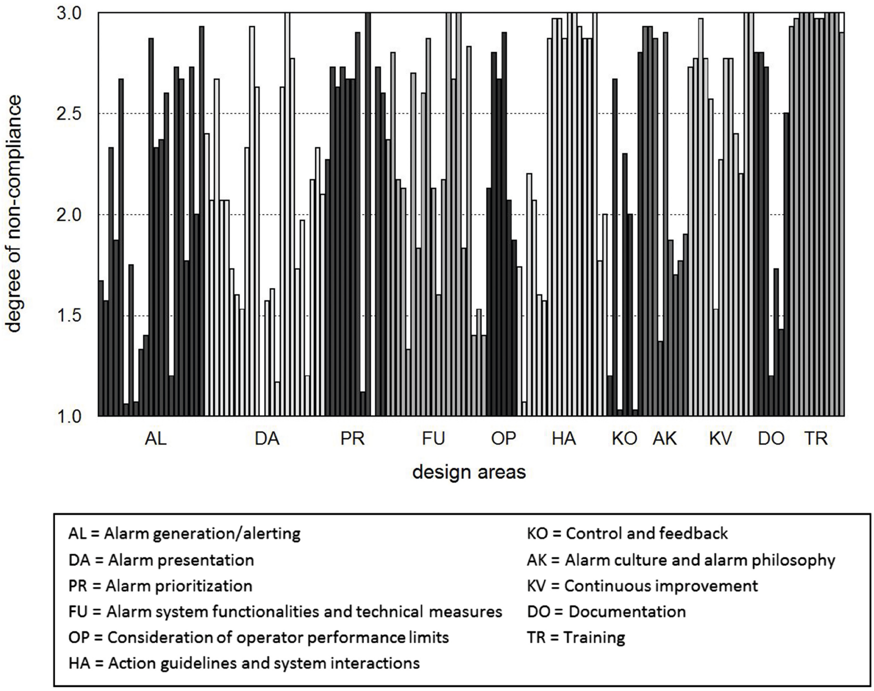

Fig. 2. Compliance with individual requirements

On a positive note, for example, new alarms (i.e. deviations from normal or nominal conditions requiring action, malfunction of plant components etc.), presented in flow diagrams for monitoring and controlling the process, were showed by special visual coding (e.g. changing symbols, colors or dynamics of the plant components or parameters) in all examined workstations. They were usually presented in signal colors, so that they stand out clearly from other (non-alarm) process information in order to attract the attention of the control room operators. On the other hand, in some cases the color contrast to the normal state or to the entire flow diagram (background) could or should have been larger; e.g. in some cases – and potentially misleading – red is used not for alarms only but also as a color for a medium and the medium-carrying pipes or valves are also shown on the flow diagram in saturated red (i.e. red = alarm and red ≠ alarm), which can lead to confusion.

In most cases, retrievable or permanently open trends were available, which enabled the control room operators to recognize changes in process parameters or approaches to alarm limits at an early stage (before an alarm occurs) and thus to be able to act proactively. However, again there was a problem that the colors used for illustrating trends sometimes did not differ significantly from the background (for example, dark blue trend lines against a black background, light green lines on light gray).

Interestingly, the participating companies had dealt with the possibility of hacker attacks and provided appropriate measures to prevent unauthorized access, albeit not always during the construction of a control room, but at least in the later stages. However, in this study it could not be verified whether or to what extent the measures taken were actually effective in the event of an outside attack into the system.

On the other hand, it seems alarming that for nearly two-thirds of the systems under investigation alarms were not prioritized according to their importance and urgency. In these cases, instead, the control room operators had to make their decisions ad hoc based on their know-how and experience, with a view to which alarm/alarms they had to deal with first in the respective situation. This deficiency seems to be important in critical situations, in particular when the alarm rate increases and the operator has to make quick decisions in the case of a major disturbance.

In order to identify the cause of the problem and to derive appropriate measures, only the text of the one-line alarm message was available to most control room operators. Help systems with process-specific or alarm-related help texts (i.e. with further assisting information) which help operators to understand what has happened and how to respond appropriately to an alarm almost never existed and if so, only for a few selected alarms. Operators had to rely on their knowledge and experience or on the knowledge and experience of their colleagues.

In only a few of the participating control rooms, the alarm events were systematically and regularly analyzed in order to continuously monitor and improve the performance of the alarm system (e.g. reduction of alarm rate, presentation of only relevant alarms to the operator) and to optimize the stress and strain on operators. In some cases, this process was still under construction but in most cases, the alarm events as well as the operating actions were not (systematically) analyzed.

Written alarm strategies or alarm concepts were very rare and if they existed, they were sometimes seriously lacking detail. Alarm management activities or improvements to the system have mostly taken place unsystematically or only reactively, e.g. after special events or after hints from operators.

Control room operators were usually given plant training and instruction in the operating functions of the process control system in use. Specific and systematic training in dealing with alarms, high alarm rates and critical situations etc., however, were very rare. Normally, new employees are introduced to their jobs by their colleagues (sitting next to Nelly). First, they often start as an outside plant operator to get to know the plant and its processes before they come into the control room as second operator at the operating station, where they first look over the shoulder of the experienced control room operator and gradually take over monitoring and controlling of the plant. However, this investigation showed that as a result of such strategies helpful functions were sometimes not known or familiar to the control room operators.

4 Discussion

The results of this study indicate that alarm systems, at least those under investigation, including the alarm management, differ widely in their ergonomic design quality. The present findings show, from an ergonomic point of view, considerable design deficiencies and in part violations of normative design requirements. At least the design solutions under consideration did not represent the current state of the art or science. The results indicate deviations from ergonomic requirements with regard to the design of the human-machine-interface, the alarm prioritization, the alarm management and systematic operator training concerning the alarm systems and the handling of alarms.

Since the guidelines or normative requirements which served as a basis for the used checklist are evidence based, both on practical experience as well as on scientific evidence, non-compliance with these requirements must be considered a severe violation of operational safety. The amount of such violations and in part their basic character was surprising. The question thus is whether these results are representative (and for what type of population) or poorly biased.

We have no idea about the representativeness of our results for countries other than Germany, although there were international companies included in the sample. However, we had some difficulties in drawing up our sample (with process control and alarm systems as the unit of inquiry), as is usual in investigations like this. It was not that easy to get the cooperation of companies for this kind of research and in our experience, the sample is not at all representative but definitely positively biased, since it can be assumed that companies who knew they might have problems with compliance and therefore thought they would perform poorly in such an investigation, would not agree to take part in this study. In this respect, we would be willing to expect that in reality things might definitely look worse.

The results might thus suggest that the relevance of the problem is still larger than expected but this can only be tested by performing a replication study, most preferably in a different country, to see whether our results are unique or systematic.

In any case, these results should (and will) be discussed with the companies involved, in order to help them develop appropriate measures to improve their process safety. The analyses of individual process control systems yield recommendations about how to improve the situation and some of them are easy to implement, while others would require a system update or severe interventions into the system.

Discussions with labor inspectorates and worker compensation boards have been started to see how they could take up the issue and provide assistance for their companies. As this was what we learned when feeding back the results to the participating companies: They were unaware about the problem (at least about its size) and those who took part in the study did so, because they were looking for help, other than from the manufacturers of the systems. It must be admitted, that some consortia are working on these problems (e.g. ASM Consortium) but obviously there is still a lot to do.

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Assessment and Comparison of Human-Robot Co-work Order Picking Systems Focused on Ergonomic Factors

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Abstract. Order picking activities are most labour-intensive process in retail warehouse. Although order picking automation is possible, it still requires human worker's activities. There have been various order picking systems in the field for decades but after amazon's KIVA system was introduced, the interest in this field has been rising. Most advanced order picking system can be classified into AS/RS type and moving robot type. Both types are goods-to-picker systems, the purpose of the systems is reducing picker's travel time to find a locations of products and move to pick them in accordance with customer's request. In many researches, the efficiency and effectiveness of the automated order picking systems are focused on the system performance aspect. Although humans are essential actors in the order picking system and key factors for both effectiveness and efficiency of order picking process, the human factors of these systems are rarely evaluated. In this paper, we focus on the ergonomic aspects of order picking system. We compared the ergonomic factors of two types of the system- moving robot and AS/RS type using digital human modeling (DHM) application (Delmia Human) and the assessment of risk factors for work-related musculoskeletal disorders (WMSDs) was conducted. We collected the data and information of automated order picking systems which are popular and applied on the site, and created virtual work place scenarios for two order picking systems. Diverse human factors were analyzed in DELMIA software with digital manikins considering various anthropometric data.

Keywords: Human factors · Order picking systems · Human-robot co-work

1 Introduction

Over the last decades there has been a huge development of the automation of material handling in warehouse. Order picking activities are most labour-intensive process in retail warehouse [1]. Although order picking automation is possible, it still requires human worker's activities. Since customer's request are getting more diversified and requirement for small quantity order are more demanding, order picking task in retail warehouse need more high flexibility.

The order of picking activities in retail warehouse consists of lifting, moving, picking, putting, packing, and other procedures. Although these activities are very

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simple and easy, most of them are repetitive and physically required. It may bring out musculoskeletal disorders (MSD) for pickers.

There have been various order picking systems in the field for decades but after amazon's KIVA system was introduced, the interest in this field has been rising. Order picking systems evolve into robot-human co-work systems as well as task automation. The former automation system is a computer aided system that automates functions such as lights, barcodes, and conveyers, but the latest order picking system brings goods right up to the picker. In many researches, the efficiency and effectiveness of the automated order picking systems are focused on the system performance aspect. Although humans are essential actors in the order picking system and key factors for both effectiveness and efficiency of order picking process, the human factors of these systems are rarely evaluated.

There are several researches in ergonomics factors for order picking systems, most of them focused on the conceptual frame or consideration for planning [2].

A principal benefit of automation is that it can reduce the human user's workload, both mental and physical [3]. In order picking systems, to a large degree, it may can reduce human workers' physical workload. The task for robot in order picking systems is mainly information acquisition, moving to stock shelves and bringing stock bins to human workers. So in order picking systems the range of task for human workers is to find the correct item from the stock bins or shelves and put it in the order bins. Compared to the manual order picking, the range of task that human workers have to do was reduced, but it doesn't mean working hour of human workers is decreased. Human workers need to do the same task - pulling and putting items-repetitively. So it is important to evaluate ergonomic factors and disorders risk factors.

We focus on the practice of this field, compared the ergonomic factors of two types of the system- moving robot and AS/RS type using digital human modeling (DHM) application (Delmia Human) [4] and the assessment of risk factors for work-related musculoskeletal disorders (WMSDs) was conducted.

2 Human-Robot Co-work Order Picking Systems

There are various types of automated order picking systems, it can be categorized by their technologies and configurations. The most advanced systems are goods-to-person order picking systems, and that can be classified into 4 types [5].

- Mini-load ASRS(Automated Storage and Retrieval Systems)
- Carousel ASRS
- Shuttle-based ASRS
- Robotic rover systems

At the end of the system there should be order picking station for human workers. But there is a difference between the above three and the last one. The above three systems are categorized by storage/retrieval method and moving way, but they all uses bins or boxes or tote. In case of last one, the robot moves a shelf to the picker. For the human workers the two order picking systems need divergent physical activities.

2.1 AS/RS Type Order Picking Systems

In AS/RS type order picking systems totes or boxes containing goods for customer's orders are retrieved from storage racks or shelves and transported by conveyor or moving vehicles to the picking station. When the totes enter the picking station they are scanned and the monitor in front of human worker shows the quantity of items according to customer's order [6]. The picker at the picking station takes the items from the stock tote and put them into order bins. There are various forms and configurations of AS/RS order picking systems, but the picking station for human workers mostly looks like Fig. 1. A stock bin that contains items arrives in the middle of the station then picker checks the monitor that indicate the quantity of items for customer's order and take the items out of the stock bin. The order bins are placed on both sides of the stock bins. The picker moves holding picked items to the order bin and put them into the order bin.

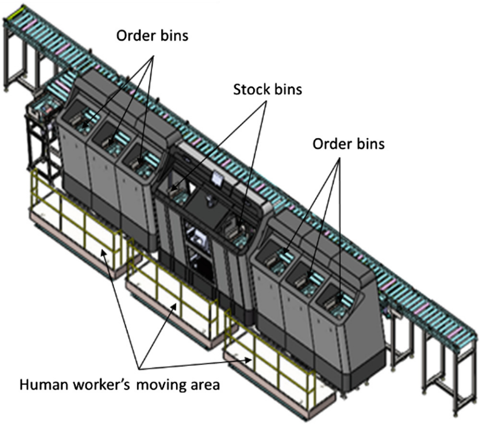

Fig. 1. Picking station for AS/RS type order picking system

2.2 Moving Robot Type Order Picking Systems

In moving robot type order picking systems, autonomous moving robots are used to move the goods from inventory zones to the human workers who accomplish picking task [7]. Figure 2 shows picking station of moving robot type order picking systems that include storage shelf brought by robot and order bins. If the robot enters picking station with storage shelf, the light on the cell that contains items to be picked flickers and the picker takes items out of the shelf. Then the picker turns around puts the items into the order bins according to customer's order.

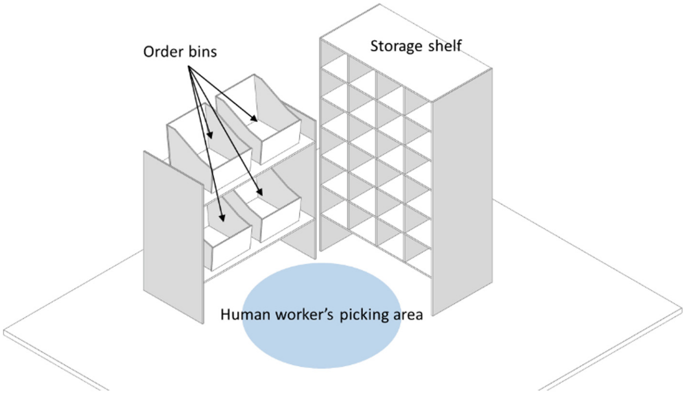

Fig. 2. Picking station for moving robot type order picking system

3 Simulation

3.1 Subjects and Task

In the past, a large portion of workers in the warehouse were male and young female workers in Korea. However the ratio of employed women and elders has increased since 2002 up to 24% in 2012 [8]. The order picking task handles relatively light weight items compared with other manual material handling tasks. In this study the subjects for digital human model is female retail warehouse workers. From video working on Amazon's warehouse we can get movements of pickers who act picking activity in Kiva systems for moving robot type order picking systems. For AS/RS type order picking systems we made a virtual working station with reference to various AS/RS manufacturers (Dematic, Opex KNAPP, Symbotic, and Vanderlande).

3.2 Posture and Task Simulation

The order picking task at picking stations consists of 3 steps. Simply from worker's point of view firstly they pick the items from a shelf or a stock bin and secondly check the items and move to the order bin/box then lastly put them into the order bin. Based on the observation from the videos we classified picking tasks of the Kiva system into 3 types as shown in Fig. 3. Task A is order picking task that include stretching arms above the shoulders to pick items from high level of the shelf, task B are modeled as picking from the shelf that its height ranges between worker's knees and shoulders. Task C include the worker's picking posture kneeling because the items to be picked placed on lower level of the shelf. In AS/RS type order picking systems the picking postures are so similar in all cases that we modeled one picking task as Fig. 4. This task include picking, walking to the order bin and putting items into the order bin, and every posture is a standing act.

Task A Task B Task C

Fig. 3. Task simulation modeling from Kiva systems

Fig. 4. Task simulation modeling from AS/RS picking station

3.3 Posture Assessment

The risk levels of working postures were assessed by RULA included in DELMIA HUMAN. It was developed to investigate the exposure of individual workers to risks associated with work-related upper limb disorders [9]. The RULA analysis examines the following risk factors: number of movements, static muscle work, force, working posture, and time worked without a break. All these factors combine to provide a final score that ranges from 1 to 7. Table 1 shows the RULA criterions [10].

Table 1. RULA evaluation criterions

Grade	Evaluation	Comfort level
1–2 (green)	Long-time maintenance and repetition of the posture are unsuitable	Acceptable
3–4 (yellow)	Further study on the change of posture is necessary	Further study is necessary
5–6 (orange)	Study and change the posture as soon as possible	Change the posture as soon as possible
7 (red)	Study and change the posture immediately	Change the posture immediately

4 Results and Discussion

Table 2 presents RULA final scores as human worker's risk assessment of two types of order picking systems. As mentioned before, the picking tasks for the moving robot type order picking system are classified into 3types related to the picker's picking posture. During the task simulation the RULA scores were recorded according to the time flow, the score range was 3–7.

Table 2. Final scores of RULA during the simulations of each order picking systems

RULA final scores	Moving robot type			AS/RS type
	Task A	Task B	Task C	
High scored posture during task simulation	3–7	3–5	3–7	3–5
	Picking items from high level shelf above shoulder	Putting items	Picking items kneeling	Picking/Putting items
	Posture A	Posture B	Posture C	Posture D

Task A and task B record the highest score (7) which means the most dangerous posture that that may result in serious personal injury. Figure 3 shows the all the postures which earn the 5 or more points. Table 3 presents the RULA score details for body parts. Posture A is picking activity for human worker to stretch her arms and pick items placed on high level of shelf. This posture put a lot of pressure on a neck, trunk and leg so the high score has been marked. Posture B and D is the activities to put the items on the tote-box, the risk factor shows on wrist and arm (score 5). Posture C is the picking activity to pick up the item from low level shelf. Since the worker should kneel, the high scores were marked from neck, trunk and leg part (Fig. 5).

Table 3. Final scores of RULA during the simulations of each order picking systems

RULA score	Posture A	Posture B	Posture C	Posture D
WRIST AND ARM	5	5	5	5
Neck, trunk and leg	7	4	6	4
Final score	**7**	5	**7**	5

This simulation shows that in ergonomic terms AS/RS type order picking systems have lower risk level for human worker's MSDs. Posture A and C needs immediate change for human workers. In most retail warehouse they treat small and light weight goods but repetitive material handling activities expose workers to physical disorders due to gradual and cumulative deterioration of the musculoskeletal system [11]. To lower risk levels for human workers, we can consider workstation adjustment, training, equipment change and work method [12].

In case of moving robot order picking systems it can be improved by removing kneeling and stretching arms above shoulders. There are some suggested methods for improving working condition which are equipment adjustment and changing stock

Posture A Posture B Posture C Posture D

Fig. 5. Simulation results – RULA high score postures

allocation strategy. To eliminate kneeling for picking items it can be considered to introduce lifting device at picking station. Changing stock allocation strategy considered order frequency may reduce risk factors on stretching activities. But both economic and ergonomic aspects for warehouse management should be considered, it needs further study to make decision of improving working conditions.

5 Conclusion

The order picking tasks by human workers in robot-human co-work order picking systems are more easy and simple than fully manual order picking systems that includes stocking, walking, lifting, carrying, pulling, pushing, picking, putting and etc. But that means the human workers need to do same task repetitively. This can cause overuse of the same muscle groups and also lead MSDs [13]. In this research we conducted virtual workplace assessment simulations for most advanced and adapted robot-human co-work order picking systems focus on ergonomic factors. We created virtual work place scenarios for two order picking systems and the assessment and comparison were conducted using digital human modeling (DHM) application. As a result AS/RS type order picking system has lower risk factors for human workers and picking station in moving robot type order picking systems needs posture change critically.

This study focuses on ergonomic risk factors on human-robot co-work order picking systems and does not consider other factors like performance and economic factors. Thus further research efforts are required to make a guideline or method to improve working conditions considering ergonomic and economic factors that influence warehouse performance.

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A Press-Through Package Design Similarity Index with Inpainting Technique

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Abstract. In order to prevent medical accidents related to drugs, not only developing safe drugs but also their proper use is important. In this paper, we proposed the method to measure look-alikeness between not only backside designs but also front side designs. Since the major difference between backside designs and front sides is the existence of tables or capsules, we applied image inpainting technique to convert the original PTP front side images to "tabletless" PTP sheet images. In order to employ inpainting technique, a neural network was used to obtain a mask image which masks tablet/capsule parts. To the resultant images, the similarity index calculation was applied as proposed in our previous study.

Keywords: Medical safety · Similarity · Fourier transformation · Image processing

1 Introduction

In order to prevent medical accidents related to drugs, not only developing safe drugs but also their proper use is important. Confusing packages of drugs are one of major causes to mix-up drugs. In order to prevent accidents caused by confusing packages, Ministry of Health, Labour and Welfare in Japan discussed and adopted countermeasures, such as notice that a Press-Through-Package (PTP) sheet, a packaging unit of medical drug tablets, needs to have a GS1 data bar defined in JIS X 0509:2012/ISO IEC 24724:2011 [1, 2]. However, it is not enough. Because medical accidents or incidents occur in the case a combination of a few or more causes happen, for example, lack of scanning barcode and confusion of package design can cause accidents or incidents. Additionally, after patients get PTP sheets, the barcode cannot be scanned and cannot prevent the confusion.

In our past study [3], we employed Fourier analysis to the periodical design of PTP sheets to extract their features. Since periodicity of the design is two dimensional, we applied two dimensional Fourier transform to the design. From the result, we clarified that we can separately deal with the atom part of design (prototile) and the periodicity of its copies. We assumed that the busy situation makes pharmacists roughly see the designs and get confused for similar ones. Moreover, we extend the idea to take account of color distribution in PTP sheets and propose a similarity index to measure

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look-alikeness [4]. However, the target of the previous study was limited to backside designs of PTP sheets.

In this paper, we propose its extended idea, which enables to measure look-alikeness between not only backside designs but also front side designs. The major difference between backside and front side is the existence of tables or capsules. Since a front side design of some PTP sheet was reportedly confused to the backside of another and caused an incident, we need to compare backside designs with the part other than tablets/capsules on front sides of PTP sheets. We, therefore, applied image inpainting technique to convert the original PTP front side images to "tabletless" PTP sheet images. In order to employ inpainting technique, a neural network was used to obtain a mask image which masks tablet/capsule parts. To the images and backside images, we applied the similarity index calculation proposed in our previous study.

Besides, we will show the results of evaluation of our method.

2 Methodology

The confusion incident of front side and backside designs suggests that we should contrast the background images of front side designs instead of their full images. In other words, we can say that the tablets having a familiar shape and color, namely, round and white, do not cause similarity of front side images. Because of this, we erased the tablet parts from the front side image, if the tablet is round and white, before we calculate a similarity index. In order to erase the parts, we employed an image inpainting technique. Image inpainting is a method to interpolate a damaged part specified by a mask image. For our purpose, the interpolated parts were not damaged parts but the parts where tablets sit.

The following PTP image samples were downloaded from the web site of a pharmaceutical company, Sawai [5].

The main steps of our method were as follows:

1. If the tablets in a target PTP sheet were round and white, we applied an image inpainting method. We implemented this program with functions of OpenCV library. It requires a mask image file, which specifies the part to be interpolated. Since the positions of tablets depend on PTP sheet designs, we need to generate a mask image suitable for each PTP sheet. In order to generate it, we applied Image thresholding and a neural network to original PTP design images.
2. The similarity index proposed in our past study [] was used to calculate similarity. We converted the images from *RGB* color space to *L*a*b** color space, utilized Fourier transformation, applied a low pass filter and calculated the distance between them (d_F). We also calculated the difference of image shift patterns (d_{shift}).
3. In Step 2, we ignored DC components. This is because they are proportional to delta functions, and their contribution is more dominant than other components. In order to balance their contribution, we separately calculated the mean values of background images of the target PTP sheets and their Euclidean distance (d_{bg}).
4. We combined the distances, d_F, d_{shift} and d_{bg} with their corresponding weight ω_F, ω_{shift}, ω_{bg} as:

$$d_{diff} = \omega_F d_F + \omega_{shift} d_{shift} + \omega_{bg} d_{bg}. \tag{1}$$

Though the values of d_F and d_{shift} are comparable, d_{bg} tends to be less than them. We, therefore, set $\omega_F = \omega_{shift} = 1$ and $\omega_{bg} = \gamma = \frac{\overline{d_F}}{\overline{d_{bg}}} > 1$, where $\overline{d_F}$ and $\overline{d_{bg}}$ are average values of d_F and d_{shift}.

We normalized the distance d_{diff} by dividing it by its maximum value:

$$D_{diff} = \frac{d_{diff}}{\max(d_{diff})} \times 100. \tag{2}$$

Figure 1 illustrates the results with $\omega_{bg} = 1$ and $\omega_{bg} = \gamma$. In the case $\omega_{bg} = 1$, the background color (yellow) is not well reflected on the distance. Instead, in the case $\omega_{bg} = \gamma$, the closest design has the same background color and, therefore, we can expect the least D_{diff} gives the most similar PTP sheet design.

Fig. 1. The effect to introduce γ. (Left) the PTP sheet design with the least distance for $\omega_{bg} = 1$, (right) the design with the least distance for $\omega_{bg} = \gamma$.

2.1 Image Thresholding

In Step 1, we need to generate a mask image. In order to extract the positions of tablets, we utilized image thresholding technique (Fig. 2):

i. The color of the image was converted into a gray scale image.
ii. We applied image thresholding to the gray scale image.
iii. Though we obtained fine diagonal lattice patterns as a background, we need to fill the background with black. Therefore, we utilized connected-component labeling and filled the connected components with black color.

2.2 Neural Network

As we can see Fig. 2., there are still unnecessary white dots. In order to remove them, we employed a feed forward neural network.

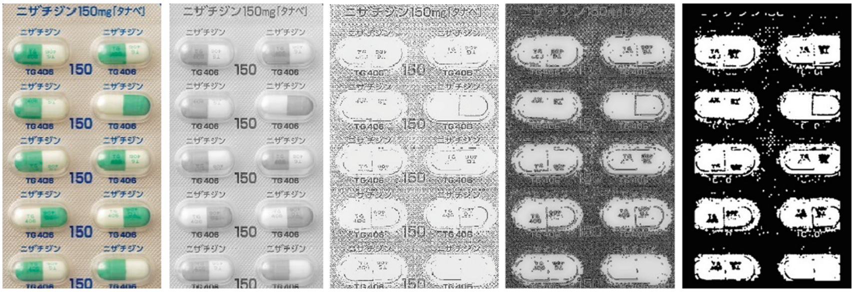

Fig. 2. An example of image thresholding results.(Most left) an original PTP sheet image, (second left) its gray scale image, (center) the result of image thresholding, (second right) the result of connected-component labeling, (most right) the image with black color filled background.

We regarded a 5 × 5 sized square as an input of the neural network and 5 × 5 sized output, which was expected to output a square image without the unnecessary white dots. The hidden layer had 25 neurons. The neural network scans 5 × 5 sized square regions without overlap in the image.

We trained the neural network with a training set, an image obtained in Sect. 2.1 as input and its corresponding mask image made manually as output.

After the training, we applied the network to the resultant images of image thresholding, and obtained a source of mask image required by image inpainting.

Figure 3 illustrates the result.

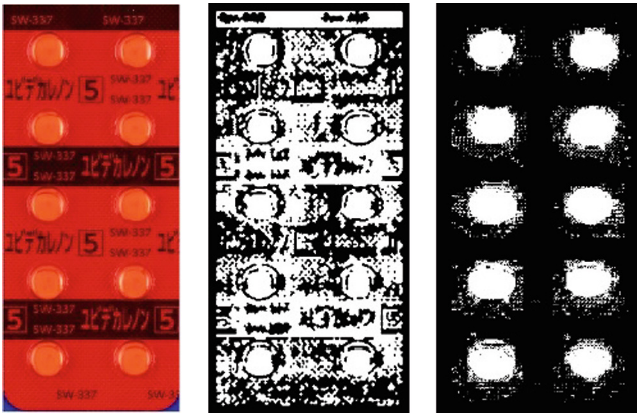

Fig. 3. An illustration of a generated mask image source (Left) an original PTP sheet design image, (center) a resultant image of image thresholding, (right) an output of neural network

2.3 Extraction of Tablet Portion Rectangles

In order to obtain the mask parts, which we call tablet portion rectangles, we again apply connected-component labeling to the white colored part where tablets exist. After that, in order to remove residual noise, we applied dilation. From the result, we calculated the centroid $\boldsymbol{x}_c$, the height h and the width w of each white part. The rectangle with average height $\bar{h}$ and weight $\bar{w}$ was located at each $\boldsymbol{x}_c$.

Figure 4illustrates the result.

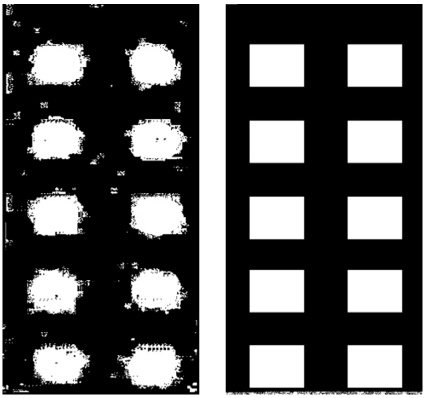

Fig. 4. Extraction of tablet portion rectangles. (Left) an mask image source, (right) an output of neural network

2.4 Application of Image Inpainting

With the mask image obtained in Sect. 2.3, we applied image inpainting to PTP sheet designs (Fig. 5).

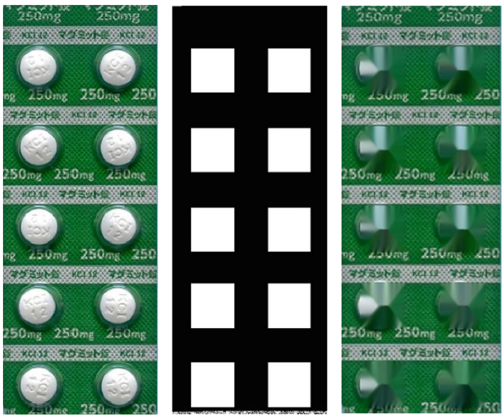

Fig. 5. Application of image inpainting. (Left) an original image, (center) its corresponding mask image, (right) an output of image inpainting

3 Evaluation

In order to evaluate our method, we conducted an experiment, where we compared the values of D_{diff} with the responses of subjects.

3.1 Method

We randomly selected two target PTP sheets (Fig. 6) and used their foreground images (*Pa* and *Pb*). Moreover, we selected three PTP sheets for each of the target sheets, which have smallest, medium and largest $\boldsymbol{D_{diff}}$ values to the target (*Pa-1, Pa-2* and *Pa-3* in Fig. 7 for *Pa* and *Pb-1, Pb-2* and *Pb-3* in Fig. 8 for *Pb* respectively). We combined each of the target PTP sheets and each of the selected sheets as pairs.

Fig. 6. The target PTP sheet images. (Left) itopride (*Pa*), (right) calcitriol (*Pb*). We used their foreground images (left in each of above images).

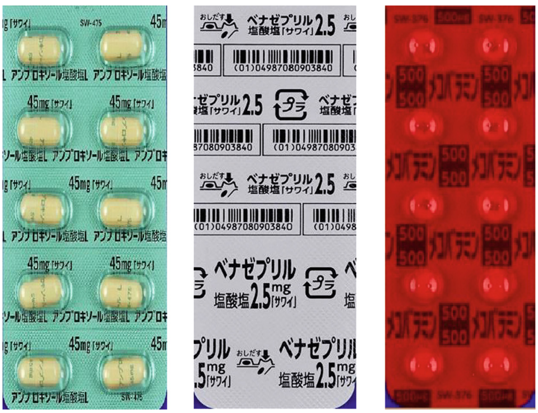

Fig. 7. The PTP sheet images compared with *Pa*. The left image has the least $\boldsymbol{D_{diff}}$ value (*Pa-1*), medium value (*Pa-2*) and the largest value (*Pa-3*).

Fig. 8. The PTP sheet images compared with *Pb*. The left image has the least $\boldsymbol{D_{diff}}$ value (*Pb-1*), medium value (*Pb-2*) and the largest value (*Pb-3*).

The pairs were presented to subjects for two seconds in order to simulate busy situation for pharmacists during drug preparation []. After the presentation, the subjects answered their extent of similarity by showing the value between 0 (dissimilar) and 100 (same).

The subjects were 10 university students.

3.2 Results and Discussion

Table 1 shows the mean values of subject responses for similarity between target images and compared images, and their corresponding D_{diff} values.

Table 1. The mean values of subject responses and $\boldsymbol{D_{diff}}$ values.

Target images	Compared images	Responses by subjects (mean values)	D_{diff}
Pa	*Pa-1*	73.9	24.7
	Pa-2	87.3	41.9
	Pa-3	92.6	100
Pb	*Pb-1*	36.0	22.9
	Pb-2	64.4	44.1
	Pb-3	85.7	100

Firstly, we can see the tendency that the mean values of subjects' responses increase, if the values of D_{diff} increase.

Secondly, we noticed that the mean value of responses about the pair *Pa* and *Pa-1* is much larger than its corresponding D_{diff} value, though it is less than the mean values of other pairs. Though both *Pa* and *Pa-1* were front side, our method did not apply image inpainting to the images, since the color of capsules in *Pa-1* was yellow. This occurred, even though the tablet/capsule parts were not excluded in D_{diff} calculation. This suggests that we need to increase the contribution of tablet/capsule colors in D_{diff} calculation.

Finally, both the mean value of responses and D_{diff} value between the pair *Pb* and *Pb-1* were small. We should notice that *Pb* was front side and *Pb-1* was backside. This suggests that the use of front side designs excluding tablet/capsule parts have a crucial role on similarity calculation in the case we compare the front side of some PTP sheet with the backside of other sheet.

4 Conclusion

In order to ensure the proper use of drugs, especially tablets and capsules, we proposed the method to measure similarity between both front side and backside designs of PTP sheets.

Since the major difference between backside images and front side images is the existence of tables or capsules, we used a neural network to obtain a suitable mask image to erase tablet/capsule parts by image inpainting technique. We also defined the distance, D_{diff}, with a coefficient γ for the contribution of background color d_{bg}. The correction by γ balanced the contribution from the variance of design and the contribution from background color, and provided us with the close PTP design image having the least D_{diff} value.

In the future, we will improve the definition of D_{diff} to include the contribution of colors of tablets/capsules and the contribution of edge parts.

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Ergonomic Work Analysis of Industrial Quality Control Workstations

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Abstract. Work-related musculoskeletal disorders (MSDs) affect millions of workers in Europe and cost employers billions of Euros. Quality control workstations usually demand the adoption of awkward and uncomfortable postures for long periods, which may stress and fatigue supporting muscles and tendons, leading to the development of MSDs. An Ergonomic Work Analysis covered the working conditions of an industrial quality section and the main risks factors were highlighted. The main objectives were: to assess the actual working conditions; to establish relationships between these and the complaints workers presented; to characterize each task in terms of the associated MSDs development risk; to present preventive measures. Rapid Entire Body Assessment and Ovako Working Posture Analyzing System analyzed seventeen postures. Both methods scored three and five postures, respectively, with a high risk of developing MSDs whereas ten postures were qualified as of medium risk. Technical and organizational solutions were proposed and implemented.

Keywords: Risk assessment · Musculoskeletal Disorders (MSDs) · REBA · OWAS · Ergonomic work analysis

1 Introduction

Human Factors/Ergonomics (HFE) focuses on systems in which humans interact with all the other elements. When we talk about HFE we should have in consideration that two related outcomes are relevant: performance (e.g. productivity, efficiency, effectiveness, quality, innovativeness, flexibility, (systems) safety and security, reliability, sustainability) and well-being (e.g. health and safety, satisfaction, pleasure, learning, personal development). Reduced performance and well-being can occur when there is a mismatch between the system and human capabilities and aspirations. Thus, these two outcomes are related e.g., performance can influence well-being, and this last one can influence performance, both in the short and the long-term [1]. The possibility of performing to a high standard at work is an important prerequisite for satisfaction and wellbeing. In other words, wellbeing and performance are strongly connected and

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should be understood to promote good outcomes. When this does not occur, fatigue and work-related musculoskeletal disorders (MSDs) could arise among workers performing these jobs [2].

Quality deficiencies, wasted products, human errors and ergonomics problems often have the same cause. In many cases they can be ascribed to the design of work, workplace and environment, and to factors such as noise, light, postures, loads, pace and/or work content, among others [3]. There is strong evidence that working groups with high levels of static contraction, prolonged static loads, or extreme working postures involving neck/shoulder muscles are at increased risk for neck/shoulder MSDs. Over 40 epidemiologic studies have examined physical workplace factors and their relationship to neck/shoulder and back MSDs [4].

MSDs are one of the most common work-related ailments. Throughout Europe they affect millions of workers and cost employers billions of euros [5, 6]. In fact, work related MSDs are among the most costly health problems that society is facing today [7].

As known, at assembly work systems, workers can face to some of this risk factors. Quality control workstations usually demand the adoption of awkward and uncomfortable postures for long periods of time, which may stress and fatigue supporting muscles and tendons, leading to the development of MSDs.

An Ergonomic Work Analysis covered the working conditions of an industrial quality section and the main risks factors were highlighted.

The main objectives were: to assess the actual working conditions; to establish relationships between these and the complaints workers presented; to characterize each task in terms of the associated MSDs development risk; to present preventive measures.

2 Materials and Methods

2.1 Stages of the Study

This study comprised three fundamental stages:

- 1st stage: General characterization of the Work Situations;
- 2nd stage: MSDs risk assessment and lighting condition characterization;
- 3rd stage: Preventive measures.

The 1st stage began with the characterization of operators and the quality control workstation. Therefore, it included task's identification and characterization, in terms of prescribed objectives as well as in terms of general executing conditions. At this stage, the characterization of the work situations focused on the prevalence of complaints (physical annoyance, discomfort and pain or eyestrain).

The 2nd stage aimed to better characterize the problematic situations identified in the previous stage. Therefore, the risk of MSDs development and lighting conditions were assessed.

The 3rd stage consisted of the proposal of technical and organizational preventive measures and included an "anti-fatigue" mat study.

2.2 Data Collection and Procedures

Different methods and techniques were used to characterize the work situation and workers involved, such as:

- Conversation with workers;
- Documental Analysis (e.g.: task procedures, risk assessment and lighting assessment reports, occupational accidents reports…);
- Free/systematized and retrospective observations;
- Environmental characterization with particular emphasis on lighting conditions and dimensional characterization;
- Image/video recording;
- a questionnaire specifically developed for this purpose.

For Image/video recording, a digital camera with 4 megapixel and 1920×1080 HD resolution - Sony HD ACHO Full HD1080 handycam 4.0.

The dimensional characterization of the workstations was made using a measuring tape.

The questionnaire was based on the adapted version of the Nordic Musculoskeletal Questionnaire [8, 9] and intended to identify key parameters for the workers' characterization, evaluate their perception of the real working conditions, as well as to identify self-reported symptoms in terms of physical annoyance, discomfort or pain and eyestrain. On the first section, sociodemographic items such as gender, age, anthropometric data (height, weight, dominant upper limb), seniority and second job were integrated to better characterization of the workers. Additionally, this section integrates items to characterize the operators' relationship with the organization (such as, number of hours worked per week, type of schedule, frequency and duration of work breaks). The second section integrated items to better characterization of the activity. The operators were asked about *"the necessity for rotate between different workplaces jobs"*, *"the receive/not receive instructions before starting the activity"*, *"why they need to compare different pieces under inspection" and "what is the main difficult felt when they make the pieces' inspection which have different colors? (for example: gold or grey)"*. The third section included items to determine the occurrence of musculoskeletal symptoms and respective intensity of pain (a four-level Likert scale was used, where 1-low intensity and 4-very high intensity). For this purpose a body discomfort chart was added. The musculoskeletal symptoms (annoyance, discomfort and physical pain) were assessed over the last 12 months and the last 7 days. Symptoms of pain or discomfort were recorded as occurrence of pain. In this session the presence of visual fatigue and respective frequency (a four-level Likert scale was used, where 1-very low frequency and 4-very high frequency) were also evaluated. The operators were also asked about "How often they feel difficult to perceive the information as a consequence of the visual strain" and "how they classify the work in terms of stress?" For the last two questions a four-level Likert scale was used (1-Never/not stressful; 2-sometimes/moderate stressful; 3-Very often/very stressful; 4-Always/Extremely stressful).

To participate in this study a verbal consent of the operators involved was previously obtained. The workers responded to the questionnaire independently and anonymously. In all cases, the confidentiality of data were insured. All workers (N = 17) agreed to participate in the study.

MSDs developing risk assessment relied on two methods: Rapid Entire Body Assessment (REBA) and Ovako Working Posture Analyzing System (OWAS). A complete description of the REBA and OWAS methods can be found in the works written by Hignettand McAtamney [10, 11] and by Louhevaara and Suurnäkki [12], respectively.

In terms of methodology, both methods were applied according to the flowchart illustrated in Fig. 1.

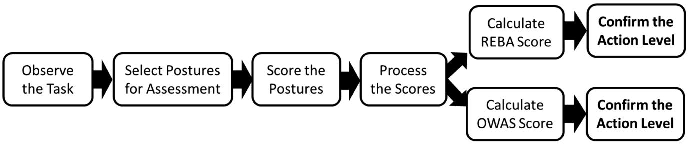


Fig. 1. Flowchart illustrating the REBA and OWAS methodology applied.

Seventeen postures were analyzed in two particular tasks accomplished in that section: "2-pieces cans' inspection" and "tops' inspection".

For postures' selection the following criteria were used, taking in account that the decision could be based on one or more criteria: most frequently repeated posture; longest maintained posture; posture requiring the higher muscular activity or the greatest forces; posture known to cause discomfort; extreme, unstable, or awkward posture, especially where a force is exerted.

Considering that different operators can use different strategies for the same task, several images were collected. By providing several task images it was possible to identify the strategy with the lowest level of risk.

As a reference, low REBA score and low OWAS score indicate that the work posture is acceptable but for the higher scores, an action is suggested [11, 12].

In REBA method load ranking was based on biomechanical criteria. Considering that scores obtained for neck, trunk and legs are combined in a particular score called score "A" and those for shoulder, elbow and wrist give a particular score "B", both were also highlighted. In REBA method, group B postures were scored for the left and the right sides, always, considering the worst posture adopted on each side.

Considering that both methods have a different action level scale, REBA and OWAS Scores were adapted to facilitate the comparison between both approaches. The relationship between each REBA Score, OWAS Score and corresponding adapted Action Level is showed in Table 1.

The illuminance (lux) level was assessed with a digital Krochmann lux meter, 106E model, which was strategically put on the surface of the workstations, following the procedures recommended by EN 12464-1:2011 standard [13].

Table 1. OWAS score, REBA score and respective action levels.

OWAS Score	REBA Score	Risk Level	Action Level	
1	1-3	**Low**	**1**	indicates that the posture is acceptable and no actions are needed
2	4-7	**Medium**	**2**	indicates that further investigation is needed, and changes may be required
3	8-10	**High**	**3**	indicates that investigation and changes are required as soon as possible
4	11-15	**Very High**	**4**	indicates that investigation and changes are required immediately

Adapted from [11],[12].

A grid system was created to indicate the points at which the illuminance should be verified for the task and the surrounding areas. Ratio of the length to width of the grid was kept between 0.5 and 2 and the maximum grid size was obtained with Eq. 1.

$$p = 0.2 \times 5^{logd} \quad (1)$$

where,

p – maximum grid cell size (m);

d – longer dimension of the area (m).

The number of points in relevant dimension is given by the nearest whole number of d/p.

All measurements were made during the night shift to register the illuminance levels exclusively due to the artificial light. Three different workbench positions (A, B and C) were used to evaluate lighting. A and B represent the positions of benches for the "tops' inspection" task, while C represents the position for the "2-pieces cans' inspection" task. Positions A and B were evaluated in order to realize if there are significant differences in terms of illuminance, since there are different types of luminaires and lamps installed on site and operators are free to place the benches wherever they want. Both A and B positions were selected by the operators on the day of the measurement and were considered to be less favorable to the occurrence of reflections and shadows which impair performance. The location of bench C corresponds to the location most frequently selected by the operators, when performing the respective task. On benches A and B, measurement were made in two different zone (Zone1, Zone2) considering the different positions of the two operators.

The correlated colour temperature (CCT) values of each lamp were registered.

For "anti-fatigue" mat study, three suppliers were contacted, in order to test three different products with the operators. Each "anti-fatigue" mat was tested for two consecutive weeks in order to involve all operators in the process. At the end of the 1st week using the "anti-fatigue" mat, operators were asked to respond to an opinion questionnaire. The most well-accepted mat would be proposed to be acquired for all workstations.

2.3 Data Analysis

For data processing the SPSS© software was used and descriptive analyzes were performed using measures of location and dispersion.

The BMI variable was calculated considering weight (kg) and height (m) data provided by the workers (BMI = weight/height^2).

The corrected Action Level 2 was considered the level for which MSDs development occurs according to both methods (OWAS and REBA).

To interpret the illuminance (lx) levels, the values recommended by EN12464-1:2011 Standard [13], were used. The corrections proposed by NF_X35-103:2013 Standard [14], taking into account age (>45), reflection and contrast factors, error relevance, task frequency and lack of natural lighting, were considered when needed. Considering the high-level visual demand in both tasks, the recommended Illuminance (lx) and the uniformity values were 750 lx and >0.7, respectively, for the task area. For the surrounding area a 500 lx Illuminance level was recommended. In terms of light color appearance, CCT above 5000K is recommended.

The illuminance level was measured at each defined point and the average ($E_{average}$), the maximum and the minimum (E_{max} and E_{min}, respectively) values as well as the uniformity (U) value were calculated.

3 Results and Discussion

3.1 Socio-Demographics' and Job's Characteristics

All workers (N = 17) of the quality control section were female and agreed to participate in the study. The age of participants ranged from 19 to 53 years (mean = 36.94 years; SD = 10.17 years). The participants weigh 68 kg on average (SD = 9.94 kg; range = 53–90 kg) were 1. 64 m high on average (SD = 0.06; range = 1.54–1.80 m) and presented an average BMI of 25.2 kg/m^2 (SD = 3.24 kg/m^2, range = 19 and 32 kg/m^2), which mean that more than 58.8% are overweight. The majority of operators (82.4%) reported that they were not involved in regular physical activities/sport. All workers were right handed.

The operators had been working in their current job for 1 to 55 months (mean = 13.94 month; SD = 17.84 month). The mean daily and weekly working hours were 8 and 40 h, respectively. All workers alternate between two shifts (Shift 1:8 h to 16 h; Shift 2:16 h to 24 h) on a weekly base. Workers are allowed to take two breaks/day (one with 10 min and another with 30/45 min duration). This means that all participants are involved in working periods longer than 2 h in each shift. All participants were paid on a piece-rate salary system. Seventy-one percent of the workers feel their work as moderately stressful. No workers had a second job.

3.2 Self-reported Symptoms

Considering the self-reported symptoms (annoyance, discomfort and pain) 76.5% of the workers reported complaints and it was possible to identify five main body regions affected: neck (47%), upper and lowerback (53%), legs (59%) and feet (29%) (Fig. 2). The results also show that the majority of the participants had experienced MSDs on the feet (100%), the lower back and the wrist (67%), the legs (60%), the upper back (44%) and the neck (12%), over the last 7 days. In terms of intensity, the majority of the situations, ranged between moderate and very high. It is important highlight that it was high or very high in 33% of cases.

Prolonged standing postures can be responsible for the complaints reported with particular emphasis on legs, feet and lower back.

Considering visual fatigue, 58.8% of the workers complained. Fifty percent out of the workers that reported visual fatigue considered that these symptoms had some impact in perceiving information. The main symptoms appointed were itchy eyes (50%) red eyes and headache (40%), blurred vision (30%) and tears or others symptoms (10%) (Fig. 3).

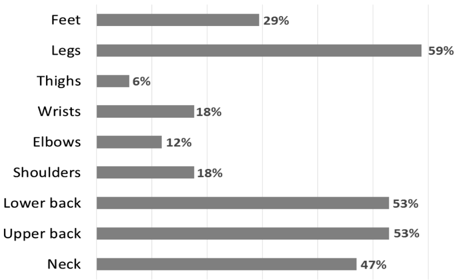


Fig. 2. Body regions presentingMSDs Symptoms (prevalence of physical complaints - annoyance, discomfort or pain).

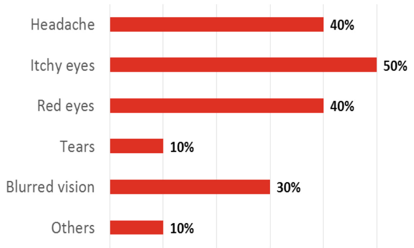


Fig. 3. Main visual fatigue symptoms reported by workers (N = 10).

3.3 OWAS and RULA Scores

As mentioned before, for OWAS and REBA assessment, 17 postures were selected in two particular tasks: “2-pieces cans’ inspection” and “tops’ inspection”. Table 2 shows the sub-tasks and respective number of postures selected to be assessed with both methods.

Table 2. Sub-tasks and respective number of postures selected to be assessed with OWAS and RULA methods.

“2-Pieces cans’ inspection”	“Tops’ inspection”
- Checking can’s defects (6) - Transportation of cardboard with cans to the lift platform (2) - Download the lift platform (1) - Put defective cans in the trash (1) - Placing the non-defective cans in the cardboard at ground level (2) - Reach the cans for further verification (1) - Complete the cardboard with the previously checked cans (1)	- Grab the sachet with tops to check (1) - Choose the tops to check (1) - Attach the tops that are inside the tube (1)

OWAS and REBA methods scored three (17.6%) and five (29.4%) postures, respectively, with a high risk (Risk level = 3) of developing MSDs whereas ten postures (58.8%) were qualified as of medium risk (Risk level = 2) (Table 3). Therefore, bearing in mind the OWAS's and REBA's results, the risk for the development of MSDs is present in 76.4% and 88.2% of the sub-tasks/postures assessed (Risk Level $\geq$ 2). These results indicate that investigation and changes are required as soon as possible or that further investigation is needed, and changes may be required.

Considering the OWAS results, the three worst postures presenting high risk for MSDs developing were: *Reach the cans for further verification*, *Placing the non-defective cans in the cardboard at ground level* and *Grab the sachet with tops to check*. The trunk and the Legs scores are responsible for the 1st sub-task and the last two sub-tasks results, respectively. These results can explain the complaints concerning the trunk and legs reported by 53% and 59% of the workers, respectively. When, considering the REBA results, the worst postures were the same highlighted with the OWAS method, one of the six postures adopted in *Checking can's defects* and one of the two postures adopted in *Transportation of cardboard with cans to the lift platform*.

The upper arms score (REBA) was $\geq$3 for 58.9% of sub-tasks/postures assessed, probably because they were flexed between 45° and 90°, sometimes with a slight abduction or with a flexion higher than 90°. The lower arms score for the majority (76.5%) of tasks was = 2 which reflects the need for operators to flex more than 100°. The wrist score for the majority (70.6%) of tasks was $\geq$2: wrists were in extension (sagittal plane) of 15° or more (47.1%) and sometimes with a radial or ulnar deviation (23.5%). The neck scores = 2 for 52.9% of the sub-tasks/postures also indicates a high proportion of neck frontal flexion above 20°. The trunk scores $\geq$2 for 88.2% of the sub-tasks/postures also indicates a high proportion of trunk frontal flexion above 20°, sometimes twisted/side bended. The legs scores $\geq$2 for 53% of the sub-tasks/postures also indicates that there was strain on the lower limbs. Only four (OWAS)/two (REBA) sub-tasks/postures assessed presented a Risk Level of 1 (e.g. an acceptable working posture- no actions are needed).

Table 3. Distribution of REBA and OWAS Scores (n = 17).

	REBA Score								
	1	2	3	4	5	6	7	8	9
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Upper arms	4(23.5)	3(17.6)	8(47.1)	2(11.8)	-	-	n.a	n.a	n.a
Lower arms	4(23.5)	13(76.5)	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Hands/wrists	5(29.4)	8(47.1)	4(23.5)	n.a	n.a	n.a	n.a	n.a	n.a
Neck	8(47.1)	9(52.9)	-	n.a	n.a	n.a	n.a	n.a	n.a
Trunk	2(11.8)	7(41.2)	3(**17.6**)	3(**17.6**)	2(**11.8**)	n.a	n.a	n.a	n.a
Legs	8(47.1)	6(35.3)	2(11.8)	1(5.9)	n.a	n.a	n.a	n.a	n.a
Score A	2(11.8)	-	5(29.4)	4(23.5)	3(17.6)	1(5.9)	1(5.9)	1(5.9)	-
Score B	1(5.9)	4(23.5)	1(5.9)	5(29.4)	3(17.6)	2(11.8)	-	1(5.9)	-
REBA Score	-	1(5.9)	1(5.9)	5(29.4)	4(23.5)	1(5.9)	-	3(17.6)	2(11.8)
Risk Level	2(11.8)	10(58.8)	5(29.4)	-					n.a - not applicable

	OWAS Score						
	1	2	3	4	5	6	7
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Trunk	5(29.4)	11(64.7)	-	1(5.9)	n.a	n.a	n.a
Arms	6(35.3)	5(29.4)	6(35.3)	n.a	n.a	n.a	n.a
Legs	2(11.8)	10(58.8)	2(11.8)	2(11.8)	1(5.9)	-	-
OWAS Score	4(23.5)	10(58.8)	3(17.6)	-	n.a	n.a	n.a
Risk Level	4(23.5)	10(58.8)	3(17.6)	-			n.a - not applicable

3.4 Lighting Conditions

The quality control area is equipped with three types of suspended luminaires (each one fitted with two lamps) with no shielding or diffusion components. Three different lamps were identified: (Lamp1:CCT = 4000 K; Lamp2:CCT = 5500 K; Lamp3:CCT = 6500 K). Table 4 summarizes the number of measuring points on each bench.

Table 4. Number of measuring points on each bench.

		Number of points	
		Task area	Surrounding area
Bench A	Zone1	8	4
	Zone2	8	4
Bench B	Zone1	8	4
	Zone2	8	4
Bench C	–	13	7
Total		45	23

The average value, the maximum and minimum values and the uniformity value of Illuminance measures are summarized in Table 5.

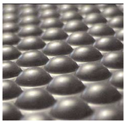
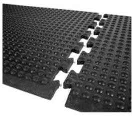
Table 5. Task and Surrounding Illuminance (E) and Uniformity (U) values obtained on each bench.

Bench	Zone	Task area				Surrounding area			
		$E_{average}$	E_{max}	E_{min}	U	$E_{average}$	E_{max}	E_{min}	U
A	1	1095	1170	1040	0.95	1114	1165	1060	0.95
	2	822	890	753	0.92	850	920	770	0.91
B	1	1088	1160	1040	0.96	1041	1120	970	0.93
	2	945	970	863	0.91	974	1020	930	0.95
C	–	892	1032	740	0.83	886	1130	700	0.79

3.5 "Anti-fatigue" Mats Study

Three "anti-fatigue" mats (A_{mat}, B_{mat} and C_{mat}) were tested with the workers. The main characteristics of each anti-fatigue mat are summarized in Table 6, as well as the operators' opinion after the 1st week of use.

Table 6. "Anti-fatigue" mats characteristics and operators' opinion.

Mat ID	Picture	Characteristics	Operators' opinion
A_{mat}		Material: 100% polyurethane Warranty: 5 years Thickness: 15 mm Available dimensions: 40 cm * 200 cm Solid mat throughout, no hollow bubbles that collapse; Anti-static properties; Silicone & latex-free Price: 127,88 €/unit (10% off for $\geq$ 10 units)	**Positive opinion**. The workers liked and complained less about their feet and legs during the testing weeks
B_{mat}		Material: Nitrile rubber Warranty: unknown Thickness: 14 mm Available dimensions: 60 cm $\times$ 200 cm Good resistance to slipping; Bevelled safety edges on all 4 sides; Bubble-like surface assisting in the stimulation of blood circulation Price: 79.20 €/unit or 1214.86/full roll (60 cm * 18.3 m)	**Positive opinion.** The workers liked but reported preference for the A_{mat}
C_{mat}		Material: soft PVC sponge mat and High durability resilient rubber base. Anti-slip; anti-fatigue; oil and grease resistant; Cleaning Warranty: 1 year Thickness: 12.7 mm Price: not available	**Negative opinion**. The workers didn't like it and after the 1st week of testing they said that they prefer not to use it

4 Proposed Solutions

As known, Organizational and Technical solutions involve different costs to the company. Considering organizational solutions are easier to implement, have short-term effects, and are affordable for the company we will present them first. At the end, some technical solutions are proposed as well.

Operators should be trained to be aware of their postures and better understand the MSDs etiology. They should be encouraged to use the means at their disposal such as gloves, lift platform, anti-fatigue mat and hearing protectors,… Sensitize and train workers to take an active role in the work situation by proposing improvements and give opinion about other proposals.

Marks on the pavement should be made to identify the places where the operators should place benches (they currently place the bench in a random manner). This would prevent workbenches from being inadequately oriented in relation to the current arrangement of the luminaires, and minimize light reflections. Figure 4 shows the proposed marks on the pavement (230 cm × 70.5 cm), where operators should place the benches.

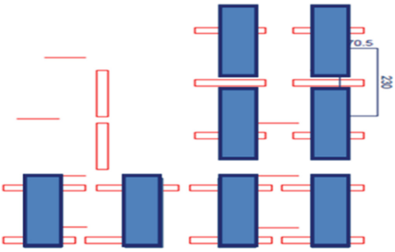


Fig. 4. Blue mark on the pavement to identify the place where the operators must place the benches.

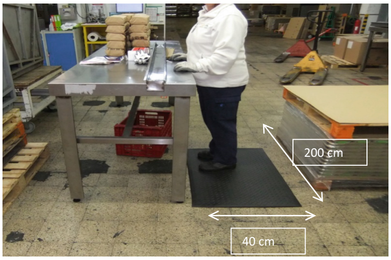


Fig. 5. Anti-fatigue mat (dimension recommended) and respective position on workstation.

Considering the positive impact observed during the "Anti-fatigue mat" testing we advise the A_{mat} to be acquired for each workstation, with the following dimensions: 200 cm * 40 cm (Fig. 5).

Acquisition and assembly of wheels on the benches would have a positive impact, since they have to be moved as required. Nowadays, the operators struggle to move the benches alone.

Acquisition of benches with adjustable height, since it is necessary to adjust the height of the work surface. The height of the benches should vary between the height of the worker's elbow and the height of his shoulder. Accurate measures are not suggested due to the great diversity of operators and each operator should adjust the working plane to his own height.

Considering that this is a temporary workstation and there are problems in terms of acoustic, thermal and lighting environment, a solution to solve these problems was thought. The solution integrates a metallic structure (Fig. 6) which consists of pillars and an overhead grid, in which luminaires would be installed, as well as an air conditioning system to control the thermal environment. Since the structure has no walls, removable panels (Fig. 7) were considered. These panels may all be open, thus forming a completely covered area. Since it is a temporary workstation, when the panels are in a corner, the area could be used for other type of tasks and still be tidy.

Fig. 6. Example of a metallic structure.

Fig. 7. Example of panels applied to the metallic structure to isolate thequality control workstations.

5 Conclusions

This study has revealed that the work done in these quality control workstations entails risks factors for its operators which may be responsible for the development of musculoskeletal disorders and visual fatigue complaints. As a limitation of this study we can highlight the short case study design which not allowed us to study the influence of workstation comfort and risk factors on the incidence of musculoskeletal complaints.

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Fatigue and Performance

The Exploration and Analysis of the Influence Factors for Staff Interactive Relationship

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Abstract. To improve the staff interactive relationship and promote the development of the enterprise, we deliver the questionnaire of "The influential factors of staff interaction relationship" to the staff of an enterprise. Software SPSS is used to analyze and verify the collected data. The structural equation model and confirmatory factor analysis are used to study the influential factors of staff, and we also use them to analyze the relationship between the various factors and the level of staff interactive relationship. The result of the study shows that the overall influential factors of staff index of this enterprise is 69.8, and it's in the middle grade. In addition, the communication skills of the staff and the external environment of the enterprise need to be improved.

Keywords: Interactive relationship · SPSS · Structural equation model · Analysis of factors

1 Introduction

The interaction of employees refers to the sum total of the interaction between employees and the exchange of people, objects and environment in the production activities. Researches show that employee's sense of belonging, the degree of harmony between employees and enterprise production safety are closely related to the interaction between employees [1, 3].

At present, there are fewer researches on the interaction relationship in the academic circles. In 1996, Hartline and so on [4] constructed the service staff management model, and they incorporated the interaction between employees into the research field of service interaction. And then, the researches of interaction between employees started. Driscoll and Randall [5] thought that in the process of interaction, if employees get more support and help, they will be more emotional commitment as feedback and reward. Wilson [6] had found that employees are more likely to share the important information with their leaders if they have a better interaction with their leaders.

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Hupei [7] had found that the interaction relationship has an important influence on employee's satisfaction. Wei Haiying and so on [8] proposed that we can establish a good employee interaction by the decision-making participation, resource sharing, organizational synergy and supervision. Other references [9–11] on the study of the interaction are simple speculative exploration and qualitative analysis of the discussion. Consequently, in order to deeply study the employee interaction, this paper will study the impact factors of the interactive relationship from the perspective of people, objects and environment. The data are collected by compiling and issuing the questionnaire on the factors affecting employee interaction. This paper builds model though SEM and it uses qualitative and quantitative methods to analyze the impact of the various factors on the impact of interaction between employees. Thus, it achieves the purpose of enhancing the interaction relationship between employees.

2 Design the Scheme of Investigation

2.1 Design of Questionnaire

On the basis of collecting and sorting a large amount of literature data, using SEM to analyze the influencing factors of employee interaction. The influencing factors of the interactive relationship are divided into four latent variables, which are personal

Table 1. Observation variable table

Latent variable	Symbol	Observed variable
Personal attribute	A_1	Effect of position level on interaction
	A_2	The importance of character in interaction
	A_3	The role of interest in interaction
	A_4	The influence of cultural level on interaction
Personal accomplishment	A_5	Work attitude in interaction
	A_6	Professional ethics in interaction
	A_7	Personal image in interaction
	A_8	Expression of the way of thinking in the interaction
	A_9	Performance of work ability in interaction
Communication skills	A_{10}	Good at controlling their own emotions
	A_{11}	Good at expressing their own ideas
	A_{12}	Good at listening to other people's expression
	A_{13}	Good at understanding other people's intentions in communication
	A_{14}	Good at reflecting their own mistakes in communication
External environment	A_{15}	Democratic communication environment
	A_{16}	Relaxed communication atmosphere
	A_{17}	Smooth communication channels
	A_{18}	Complete communication equipment
	A_{19}	Perfect communication system

attribute, personal accomplishment, communication skills and external environment. Among them, personal attribute, personal accomplishment and communication skills are used as endogenous latent variables of the model, and the external environment as a model of exogenous latent variables. According to the above, nineteen individual observation variables which may influence the employee interaction are designed. Detailed descriptions are shown in Table 1.

The questionnaire is adopted Likert Scale. In terms of measuring scale, the paper set up three levels of impact. The value of 1 indicates that “low”. The value of 3 indicates that “medium”. The value of 5 indicates that “high”. According to the different indicates of enterprise employees correspond with their own views of the score.

2.2 Determination of Sample Size

The sample random survey is adopted in this questionnaire. A total of two hundred and thirty-six questionnaires are issued. Among them, two hundred and twenty-five questionnaires are received and the effective rate is 95.3%. The survey participants are local business people, including employees, team leaders and senior management leaders. The numbers are two hundred and four, fifteen and six respectively. Its distribution ratio is shown in Fig. 1.

Fig. 1. Statistical description of the different positions in the enterprise.

2.3 Reliability and Validity of Questionnaire Data

Reliability of Questionnaire Data

Reliability refers to the degree of stability or consistency of the measurement results. If the reliability coefficient is above 0.8, we believe that the questionnaire reliability is high; 0.7–0.8 can be accepted; 0.6–0.7 can be accepted reluctantly and under 0.6 the questionnaire is not credible. The applicability test of factor analysis by KMO and Bartley sphere test in SPSS. If the KMO value is above 0.5 and the significant level is below 0.05, we believe that the factor analysis is suitable for the analysis.

From Table 2, we know that the KMO value is 0.818, it more than 0.5. The significant level is 0, it indicates that there is a correlation between the factors and the model is suitable for factor analysis. From Table 3, we know that the reliability coefficient of each latent variable all greater than 0.7 in Alpha Cranbach, and it shows that the design of the model is suitable for measuring items.

Table 2. Results of KMO test and Bartlett test

KMO test		0.818
Bartlett ball test	Chi square test	692.511
	Freedom	134
	Significant level	0.000

Table 3. Alpha Cranbach reliability analysis

Latent variable	Number of measurable variables	Alpha Cranbach reliability coefficient
Personal attribute	4	0.912
Personal accomplishment	5	0.756
Communication skills	5	0.849
External environment	5	0.821

Validity of Questionnaire Data
In this paper, the structural equation theory is used to construct the model. The construct validity of the scale is assessed by the model fit of confirmatory factor analysis. So as the validity of the data is transformed the index evaluation in SEM evaluation.

3 The Establishment of SEM

3.1 Establishment of SEM Model

We use LISREL software to build the initial model. By using the method of maximum likelihood estimation, the path coefficients and the coefficients are normalized. The results are shown in Fig. 2.

3.2 Overall Fitting Evaluation of the Initial Model

The main parameters of X2, df, X2/df, RMSE, CFI, NNFI and IFI are tested to analyze the goodness of fit of the model [12]. The parameters of each fit of the initial SEM model are shown in Table 4.

From Table 4, we know the RMSEA and IFI indicators have not met the requirements, the overall degree of the initial model is not high, we need to further modify the initial SEM model, and make it more in line with the data reflected by the variable relationship.

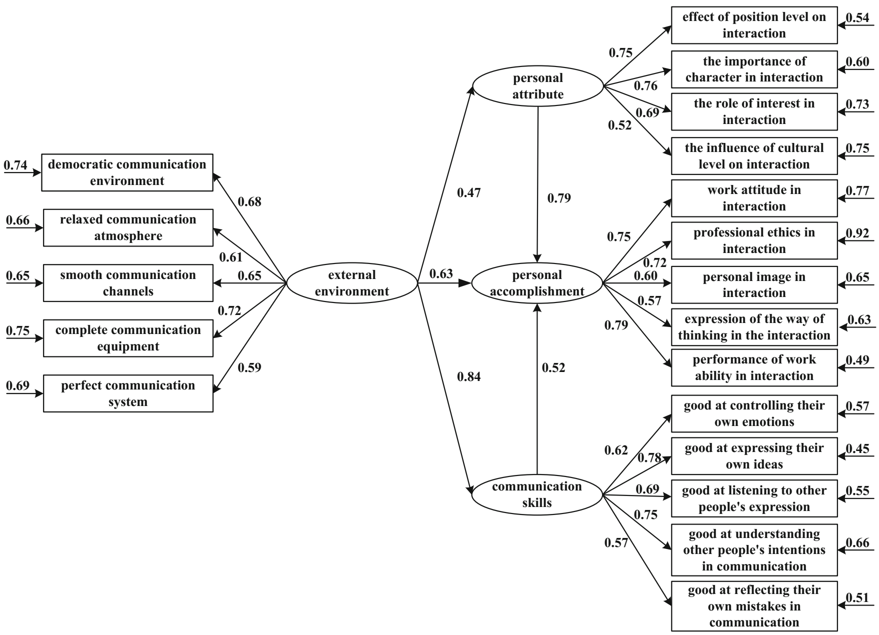

Fig. 2. Initial model path diagram

Table 4. Test results of the goodness of fit of the initial SEM model

Fitting index	X2	df	X2/df	RMSEA	CFI	NNFI	IFI
Estimated value	167.29	96.00	1.74	0.07	0.90	0.87	0.90
Judgment standard	Near freedom	The smaller the better	≤ 2	≤ 0.06	≥ 0.9	≥ 0.9	> = 0.9

3.3 Adjustment of the Model

Modified index method is used to modify the initial model. We select the path of the MI value is relatively large to adjust, and theoretical analysis according actual situation. The modified model path diagram is shown in Fig. 3.

We parameter estimate the modified model, and we can get the values of the main parameters. They are shown in Table 5.

From Table 5, we can see that all the goodness of fit indexes of the modified model can meet the requirements. It shows that the fitting effect of the modified model is better.

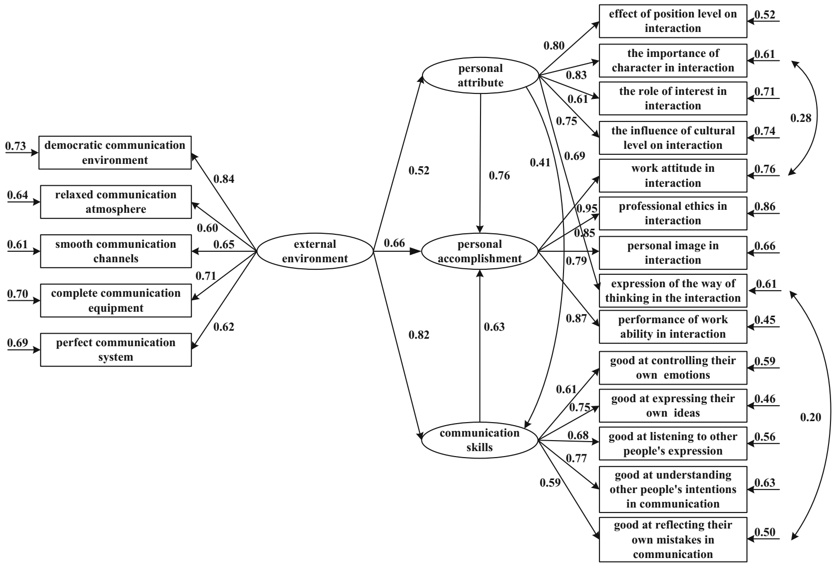

Fig. 3. Modified model path diagram

Table 5. Test results of the goodness of fit of the modified SEM model

Fitting index	X2	df	X2/df	RMSEA	CFI	NNFI	IFI
Estimated value	128.34	95.00	1.35	0.04	0.96	0.93	0.96
Judgment standard	Near freedom	The smaller the better	≤ 2	≤ 0.06	≥ 0.9	≥ 0.9	≥ 0.9

4 Model Analysis

4.1 Influence Score of the Factor Index

According to the results of SEM calculation, we can get the score of four aspects of the enterprise, so as to make a quantitative evaluation of the interactive relationship of the enterprise. The score of the enterprise is 95 points (19 * 5 = 95), and the score is divided into five levels. The first level is excellent (85–95). The second level is good (75–85). The third level is average grade (65–75). The fourth level is up to standard (55–65). The fifth is not qualified, the score is less than 55. Though the calculation, the comprehensive influence factors of the interactive relationship are shown in Table 6. Among them, the weight is the load factor corresponding to the observation index.

Table 6. Influence score of factor index

Latent variable	Observed variable	Weight	Weight value	Comprehensive impact score
Personal attribute	A_1	0.80	18.40	69.80
	A_2	0.83		
	A	0.61		
	A_4	0.75		
	A_8	0.69		
Personal accomplishment	A_5	0.95	17.30	
	A_6	0.85		
	A_7	0.79		
	A_9	0.87		
Communication skills	A_{10}	0.61	17.00	
	A_{11}	0.75		
	A_{12}	0.68		
	A_{13}	0.77		
	A_{14}	0.59		
External environment	A_{15}	0.84	17.10	
	A_{16}	0.60		
	A_{17}	0.65		
	A_{18}	0.71		
	A_{19}	0.62		

4.2 Model Analysis

(1) The relationship between the latent variables

From Fig. 3, we can see the path coefficients that between external environmental factor and personal attribute factor, personal accomplishment factor, communication skills factor are 0.52, 0.66 and 0.82. It shows that there is a positive correlation between external environmental factor and personal attribute factor, personal accomplishment factor and communication skills factor, and if external environmental factor increases 1%, it will let personal attributes factor, personal accomplishment factor and communication skills factor increase 0.52%, 0.66% and 0.82%. The path coefficients that between personal attribute factor and personal accomplishment factor, communication skills factor are 0.76 and 0.41. It shows that if personal attribute factor increases 1%, it will let personal accomplishment factor and communication skills factor increase 0.76% and 0.41%. The path coefficient between communication skills factor and personal accomplishment factor is 0.63. It shows that if communication skills factor increases 1%, it will let personal accomplishment factor increase 0.63%.

(2) The relationship between the latent variables and the observed variables

We analyze the relationship between personal attribute factor and its observed variables. The coefficient of character (A2) is the largest, the position level (A1) followed by A2, next is the cultural level (A4) and the expression of the way of thinking (A8), finally is the interest (A3). It shows that character has a significant impact on the employee interaction relationship. At the same time, when the enterprise pays attention to the staff character, it also should help the staff to establish correct outlook on life and values. On the basis of mutual trust, the enterprise should encourage employees communicate with each other, so as to overcome the staff's self-closing psychology.

We analyze the relationship between personal accomplishment factor and its observed variables. The coefficient of the work attitude (A5) is the largest, the work ability (A9) followed by A5, next is the ethics (A6), and finally is the personal image (A7). The coefficients of the four observation variables are relatively large, which show that they have an important impact on the interactive relationship. Therefore, enterprise managers should play an exemplary role. Firstly, the manager should correct his own work attitude. Secondly, the enterprise should establish a targeted and practical supervision mechanism and incentive mechanism, because it can enhance the staff's self-control, stimulate the labor and create enthusiasm. Finally, the enterprise should pay more attention to the development needs of individual employees, adhere to the "people-oriented" management philosophy and reduce the waste caused by "not doing", so as to arouse their working interest and cultivate their positive attitude.

We analyze the relationship between communication skill factor and its observed variables. The coefficient of the good at understanding other people's intentions (A13) is the largest, the good at expressing their own ideas (A11) followed by A13, next is the good at listening to other people's expression (A12) and the good at controlling their own emotions (A10), and finally is the good at reflecting their own mistakes (A14). It shows that the skill which good at understanding other people's intentions can urge communication between employees, and it is more conducive to improving the interaction relationship between employees. Enterprise should cultivate employees the ability of empathy. When employees communicate with each other, they can put their selves in the position of the other side to think. At the same time, enterprises also need to cultivate the staff to establish a fair, inclusive attitude and reduce individualism and autocratic heart. In order to better understand the intentions of others.

We analyze the relationship between external environmental factor and its observed variables. The coefficient of the democratic communication environment (A15) is the largest, the complete communication equipment (A18) followed by A15, next is the smooth communication channels (A17) and the perfect communication system (A19), and finally is the relaxed communication atmosphere (A16). It shows that the democratic communication environment is the basic condition to improve interaction. Enterprise managers should increase the open opportunity to communicate with the employees, and fully enhance the interaction between employees and managers. At the same time, managers should adopt the reasonable suggestions of employees. Managers and staffs should strengthen the democratic communication environment together.

5 Conclusion

Through the questionnaire survey of the employees of the enterprise, we use SEM to explore and analyze the influencing factors of the employee interaction relationship. We can get the following conclusions:

(1) The impact score of enterprise employee interaction relationship is 69.8, which is in the medium state. It shows that the overall interaction relationship between employees in the enterprise is general.
(2) No matter which factor variable is affected, it will affect the other factors and the level of interaction relationship. We must maintain a high score of each factor, so as to improve the overall interaction relationship effectively.
(3) The personal attribute factor has the highest score, followed by the personal accomplishment factor and the external environment factor, and the score of the communication skills factor is the lowest. In this regard, enterprise should pay more attention to improve the communication skills of employees and managers. For instance, when employees communicate with each other, they can put their selves in other's shoes, so as to better understand the intentions of others. When managers communicate with employees, managers can adopt the incentives and other mechanisms, so as to improve the quality of communication between managers and employees effectively.

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The Effects of Night Shift Schedule on Workers' Life and Wellbeing: Gender Differences

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Abstract. The impact of night shift work on workers' wellbeing and the relationship to gender is currently unclear. This study identifies the potential health impact of night-shift between male and female workers. Ninety workers (M = 45, F = 45) were surveyed. Males reported being sad and depressed 12% more than females. Females reported a higher incidence (18% higher) of finding it more difficult to sleep after work. Males were 7% more nervous and very fidgety than females after nightshift work. Females are more likely (8%) than their male counterparts to "more than usual have difficulty making decisions after work." The effects of night-shift schedule on both genders demands an immediate intervention. This study could be a wake-up call for the OSHA to intervene in workers' schedules.

Keywords: Circadian rhythm · OSHA · Psychosocial · Fatigue · Health

1 Introduction

The loss of sleep from time to time is not uncommon, but the consistency of night shift work can take a toll on a worker's sleeping pattern and impact their health in a myriad of ways, if left unchecked. Today many industrialized countries require shift systems of work, which include working afternoon and night, in order to ensure the functionality of the system. Shift work is common in the healthcare industry, security, communication, entertainment and transportation in urban cities (e.g., New York, Chicago, Baltimore City, etc.). The Institute for Work and Health (IWH) reports that there is strong evidence that night, evening, rotating and irregular shifts are associated with in increased risk of occupational injury due to worker's fatigue, less supervision and co-worker support during non-daytime shifts. Knowingly and unknowingly shift workers are battling with problems that require them to ignore their diurnal nature, because their eyes are open to work at the times they should be closed to sleep. Folkard [1] considered this as desynchronization of the circadian periodic functions. Folkard perception about human nature was acknowledged in Costa's [2] recent study saying, "Staying awake at night and trying

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to sleep during the day is not a physiological condition for diurnal creatures such as humans, who are hence forced to adjust their psycho-physio-logical state by a phase shift of the daily fluctuation of biological functions, which are normally activated during the day and depressed during the night. This phase shift occurs at a speed of about one hour per day and can widely vary according to the duration and extension of night duties along the shift schedule" p. 2.

According to Costa [3], night shift can increase worker absenteeism and disrupt female hormonal activity as well as their reproduction function. The Bureau of Labor Statistics [4] data report showed that nearly 15% of American full time workers work night shift, rotating shifts, or an arranged irregular schedule, out of which night shift was amounted to 3.2%. Many American employers do not recognize or understand the correlation between workers working hours/schedule and their performances. Shift schedules can be associated with different health effects such as cardiovascular disease, gastrointestinal disease, increased accident risk, disturbed sleep and increased fatigue according to Åkerstedt [5]. The night shift schedule disturbs physiological rhythms and the sleep–wake cycle and has been proven to result in problems not only in endocrine, metabolic, and hormonal systems but also in high blood pressure, high serum triglyceride and low serum HDL-cholesterol and cerebro-vascular disease [6].

Health and safety impacts of shift schedules have been in a continuous discussion since 1980's. Many researchers have worked to assess the various occupational factors that result in health impacts of night shift [7, 8, 9]. Yet, little to no research has been done on gender differences, in this area of study. One reason may be lack of adequate information on males and females that would lead to valid results because of the different jobs, occupations, and working conditions that are usually found for each gender working night shifts. Among the few papers found in this area of study that focused on gender differences, the outcomes differ. For example, Beermann and Nachreiner [10] in a discriminant analysis report on the results of a survey on the effects of shift work on women and men under similar job conditions, gender related effects could not be found. However, the recent finding of night shift work and gender indicate different effects on men and women; pointing to a greater impacton women [11]. Paddock's finding was based on a laboratory research, while Beermann and Nachreiner study was on self-reported worker perception. It has been revealed by quantitative sleep analysis that more severe effects of night work are found on women, particularly those with children [12].

Tolerance to shift and night work is a complex phenomenon related to several aspects pertaining to different domains dealing with personal characteristics and coping strategies, family and social conditions, working situations and particularly, working hours of the organization [13]. Providing data to support gender differences for male and female on night shift schedules is still needed, due to the lack of supportive statistical data on rotating night shift work under comparable job conditions. Meanwhile, the belief that differences do exists has kept the effort alive to clearly provide the supporting data so that workers can receive the benefits that can be made available to them. As such gender-related effects of night-shift and shiftwork have been of special interest, since different effects for male and female would justify gender-related health and safety regulations at work. Therefore, this study is conducted to identify the potential health and life impact of night shift between male and female workers.

2 Materials and Method

2.1 Participants

The study population for this research included employees that routinely work night shift at a food processing company, the healthcare industry, a goods producing industry, a customer (technical) support service company, and a courier service. The companies are geographically located in mid-west America and central North Carolina. The total number of workers who participated in the survey were ninety, 45 both males and 45 females. Participants were recruited through the support of the facility's management staff along with a support letter from the Institutional Review Board (IRB) of the authors' institution. Information informing participants of any risk associated with the research was written in the informed consent form. Participants were advised to read the consent form thoroughly and to ask questions, if the need arose, before signing and giving their consent to participate in the survey. The research protocol was approved by the University IRB. Participants were grouped into three age group categories (18–34), (35–54), and (55–74). Participant ethnicities are Black or African Americans, Caucasians, Native Americans or American Indians, and Hispanics or Latinos with the predominant ethnicity being Black or African Americans.

2.2 Procedure

Data were collected using a researher-developed questionnaire adapted from a standardized questionnaire. The questionnaire was reviewed by a group of certified safety personnel and psychologist to validate its content. The questions were presented in the form of yes/no options and a Likert Scale. The yes/no options reflected what several researchers have used [14, 15] to investigate the effects of work schedule on workers. After the review, the application was submitted to the IRB for research ethic violations review. Prior to distribution of the questionnaire to various organizations, each facility was visited to obtain permission.

At each organization, the purpose of the research was explained to the management and approval was obtained before the questionnaires were released to the employees. In each organization, a sealed box with a small opening at the top was made available at the reception desk for participants to return completed questionnaires without fear of identification by any member of the management. All reponses were voluntary and anonymous. To ensure privacy, no names were requested or given by the participant. Each organization was visited up to three times per month. Questionnaires were attached with the consent form. After one month in each organization, both completed and uncompleted questionnaires were collected and were taken to the lab for data compilation.

3 Data Analysis and Results

Data collection of all respondents lasted for approximately six months. Data compilation was done with the use of Excel ® version 2010. Out of three hundred survey sent out, ninety-two copies were returned fully completed of which 49% (n = 45) were female and 51% (n = 47) were male. Ninety responders' questionnaires were treated in order to ensure equal distribution in the number of female and male gender participated in the study; 45 females 45 males. Of the ninety respondents, sixty-five percent were Black or African American, 17% were Caucasian, 12% were Hispanic or Latino and 6% were Native American or American Indian. Approximately 28% of the participants were in the age group 18–34, 60% were in the age group of 35–54, and 12% of the participants were in the age group 55–74. Table 1 shows respondents' ethnicity, age-group and gender frequency distributions.

Educational levels of all respondents follow a bell shaped curve distribution shown in Fig. 1. This describes the standard normal distribution and respondents' education level with respect to the observed population working the night shift. The majority of

Table 1. Table 1: Participants' demographic information.

Demographic information		Population	F	M
Ethnicity	Black or African American	59	29	30
	Caucasian	15	8	7
	Hispanic/Latino	11	5	6
	Native American	5	3	2
Age	18–34	25	13	12
	35–54	54	27	27
	55–74	11	5	6

*F = Female, M = Male

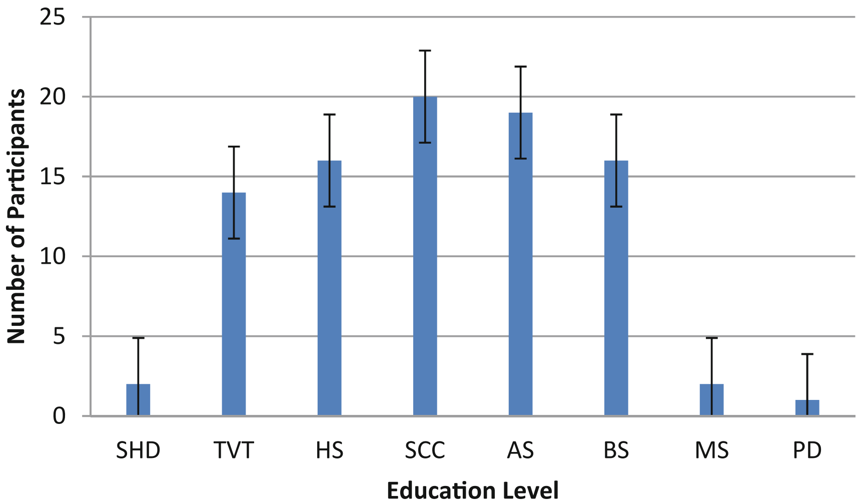

Fig. 1. Education distribution of the participants. SHD –Some High School, no Diploma, TVT –Technical Vocational Training, HS- High School Diploma, SCC – Some College Credit, AS – Associates, BS – Bachelors, MS – Masters, PD - Professional Degrees

night shift workers consist of workers with technical and vocational training through a Bachelors education and peaks at workers with some college credit. The number of night shift workers with Masers and PD declines significantly.

3.1 Health Effects

It is generally understood that the effects of work night shift have a deleterious effect on sleep. The most work place incidents/accidents happen during night work shift. This is possible as many might not have had enough sleep during the day and the body biological clock is being affected at night while working instead of sleeping. One of the findings from this study shows that 28% of the respondents experienced poor appetite. Out of this 28%, fifty-two percent were female and 48% were male. Forty-three percent of the respondents revealed having difficulty sleeping after working the night shift. Of this 43%, fifty-nine percent were female and 41% were male. Overall, females appeared to be most affected; leading their male counterparts by 18%.

3.2 Fatigue

For questions regarding respondent fatigue (low energy, mental and physical fatigue) females reported higher incidents of fatigue in two categories than their male counterparts – low energy and mental fatigue. Fifty-one percent of the respondents complained about low energy level, out of which 45% were male and 55% were female. Mental fatigue in terms of respondents' mental concentration revealed that 43% experienced concentration problems, out of which 59% were female and 41% were male. Thirty-two of the respondents' complained of difficulty making decision after working the night shift, out of which 54% were female and 46% were male. Forty-one percent of the respondents complained of physical fatigue, of which 54% were male and 46% were female.

3.3 Psychology

Night shift schedules can possibly be a psychosocial stressor. Stress occurs in a situation under pressure or inability to cope with an incident or stimulus. Twelve percent (eleven) of the respondents declared to have developed symptoms of unfavorable mental health while working the night shift. Female respondents were 70% of the population which made female 40% higher than their male counterparts reporting mental health problem. Twenty-eight percent of the respondents declared to have being depressed after worked night shift. Males, 56% of this population; 12% higher than their female counterparts.

4 Discussion

Many published articles on night shift schedules and over time working hours have revealed different effects of the schedules on workers well-being and performances [16, 17, 18]. This study sampled workers who work night shift schedule for at least 3 h daily for at least 5 days in a week and focused on the differences in the night shift effects as experienced by female and male in workplaces. Findings from this study provide evidence that night shift work is associated with poor quality of life, low energy, sadness, and depression. Findings further reveal that female are generally affected by night shift schedule than their male counterparts. The finding that night shift schedule has different health effects on female and male support Paddock [11] who first discovered that the night shift affects men and women differently, such that it reduces women cognitive function to perform their daily duties effectively. Paddock's study was a laboratory setting study on nurses and police while this study used surveys to capture the worker perception on the effect of night shift. None of the respondents of the study is a police man, yet findings are similar. Psychosocial stress and depression were confirmed by this study, which also agree with [13, 19] studies.

Generally, findings reveal that night shift schedule has greater effects on human circadian rhythms and as such deteriorate workers' health and social life, which females are greatly affected. The findings of this study in general support, the conclusions of previous studies: workers working night shift schedules are prone to negative health effect [20].

5 Conclusion

Finally, the study findings on night shift schedule support the findings of other studies. Night shift schedules inhibits human health, social life and well-being in dramatic manners. Many workers fail to realize that the effects of the night shift are not always manifested in a short period of time, but are the result of an aggregate of several circadian rhythm disruptions. The night shift schedule's adverse effects on workers based on this questionnaire is comparable to that noticed in a clinical study. The effect of night shift schedule is predominant in female workers than the male workers. Females that work night shift schedule are prone to health adverse effects than their male counterparts, simply because their body systems have been affected by the circadian rhythm disruption. Females who experience poor appetites are 4% higher than males and 18% higher in sleep difficulty. Female experience muscle fatigue easily than the males, this may be due to their body hormone system. Health wise, females have a higher incidence of mental health problems than do males. During the course of this study, the researchers experience some limitations, which limit the number of workers that participated in this study such as difficulty to obtain company management support. For future study, more attention should be given to workers health and family relationship such as marriage and friends. This study could be a wake-up call for the Occupation Safety and Health Administration (OSHA) to intervene in the night shift schedule of an organization.

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Occupational Health and Safety Dimensions and Work Outcomes in the Mental Hospitals in Ghana: The Moderating Effect of Job Satisfaction

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Abstract. Like high risk industries such as aviation and mining, occupational health and safety issues in the mental hospitals cannot be underestimated. For instance, although some conceptual and empirical studies have focused on patient safety in mental hospitals, the safety and health management of nurses in the mental health sector has largely been ignored. This paper seeks to examine the relationship between occupational health and safety management and two work outcomes such as engagement and turnover intention in a large mental hospital in Ghana. Results of the correlation coefficient indicated a positive relationship between occupational health and safety and engagement, and a negative relationship with turnover intention. The hierarchical regression results revealed a positive influence of safety procedure and safety leadership on mental health nurses engagement. In addition, only safety supervision and safety leadership had negative effect on the mental health nurses' turnover intention. Finally, job satisfaction of the mental health nurses moderated the relationships between safety supervision and safety leadership, and intention to turnover.

Keywords: Occupational health and safety · Policy · Job satisfaction · Employee engagement · Turnover intention · Mental hospitals · Ghana

1 Introduction

Unlike hazardous sectors such as aviation, mining, quarrying and fishing, occupational health and safety (OHS) in the mental hospitals has received less research attention from both academics and practitioners. In advance countries, the health and safety of healthcare workers (HCWs) in general are safeguarded through risk assessment, safe working practices, containment of hazards, usage of personal protective equipments and immunization. However, the case of mental hospitals in Ghana is very different. For example, mental health nurses who suffer physical injury due to

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aggression from mental patients are supposed to cater for themselves with their own health insurance at a registered healthcare facility or hospital.

In addition, nurses working in the mental hospitals are exposed to various forms of physical, chemical, biological, mechanical and psychosocial risk factors [37]. Hence, although mental hospitals provide healthcare facility to mental patients, the health and safety of healthcare nurses are not guaranteed due to the lack of a comprehensive and stakeholder focused laws on OHS-related issues. The few scattered pieces of legislation are not enforced due to prevailing inefficient and costly legal systems. Further, unlike some developed countries in Europe, North America and part of Asia where OHS laws have been enacted to guarantee safe and healthful working conditions for working men and women [17], the case of Ghana is extremely different. For example, in Ghana, with the exception of some statutes such as the Labour Act, 2003 (Act 651); Factories, Offices and Shops Act, 1970 (Act 328); Workmen's Compensation Act, 1999 (Act 526) and the Ghana Health Service and Teaching Hospitals Act, 1996 (Act 525), and a number of industry specific legislations which make provisions for health and safety at work, there seem to be no detailed piece of law regulating and ensuring the enforcement of health and safety standards at work. Hence, mental health nurses have no choice but to engineer their own health and safety measures to ensure their well-being and quality of life at work.

Available statistics show that 2.3 million workers die each year due to work-related injuries, and 350,000 of these deaths are attributable to occupational accidents [18]. Besides, the ILO estimates that there are 264 million nonfatal accidents each year. Furthermore, it has been estimated that globally, 3.35 million workers in the healthcare sector experience percutaneous injuries with a contaminated sharp object every year [32]. Finally, the [40] estimates that healthcare workers in Africa, the Eastern Mediterranean and Asia average about four needlestick injuries per year. Given the considerable attention and care provided by nurses to mental patients, the health of such nurses should not be taken for granted. Moreover, it should not be the responsibility of employers only but also the wider stakeholder group, including health, work and environment authorities.

Despite the fact that some empirical and conceptual studies on OHS management have been conducted in diverse sectors such as manufacturing [31], mining [5, 6], construction [41], oil and gas extraction [8, 27], small and medium-sized enterprises [23], waste management [10], and wood processing [29], there still remains to be seen a similar empirical study in the mental health sector (for exception see [21]). This study is not just timely but also imperative since it seeks to examine the relationship between OHS management and work-related outcomes in a large mental hospital in Ghana. Furthermore, it is the first study to examine the moderating effect of mental health nurses' satisfaction on the relations between OHS management dimensions and engagement as well as turnover intention in the mental hospitals in Ghana.

The rationale for choosing nurses as participants for our study is because, from an ethical standpoint, nurses have a direct interest in health and safety issues since they run the major risks of injury if provisions of the law fails to protect them. To augment the aforementioned rationale, [19] opined that employees often know more about the hazards associated with their workplace than anyone else does, as they recurrently work with them. Finally, [39] also stated that research from many countries demonstrates the positive benefits of worker participation in occupational health and safety issues.

OHS management is a multidisciplinary concept that influences both private and social lives of employees in all spectrums of work [28]. Therefore, the rationale for a good health and safety management system is to improve work conditions and employees' health in the workplace. For instance, apart from the legal obligation, all organisations have a moral duty to ensure that employees and other stakeholders affected by the actions and inactions of the organization remain safe at all times and costs [28]. Finally, in this study we assume [24] description of OHS as a multidimensional construct which includes leadership, facilities/equipment, supervision and procedure. The main research questions underpinning this study are: is there a linkage between OHS and engagement and turnover intention? Will nurses' job satisfaction affect the nexus between OHS management and work outcomes?

2 Theory and Hypotheses Generation

Drawing on social exchange theory [11], we argue that mental health nurses perception of OHS management policies and practices will influence their level of engagement and turnover intention. However, job satisfaction can also buffer this relationship so much that the more satisfied mental health nurses are with their jobs due to proper OHS management policies and practices, the more likely they are to be engaged with their organisation and the less likely they are to quit their organisation. The social exchange theory is based on the norm of reciprocity, which refers to the tendency of employees to respond to a beneficial action by returning a benefit and to harmful by returning a harm. For instance, [11] considers interpersonal relationship from two perspectives, economic and social exchange. In this context, the social exchange theory helps to explain and understand the moderating role of job satisfaction among the perceptions of nurses regarding the relationship between OHS management, employee engagement and turnover intention.

2.1 Occupational Health and Safety, and Employee Engagement

Occupational health and safety management is imperative because it helps reduce expenses related to injury and illness among workers like medical care, sick leave [36] and compensation benefit associated with vicarious liability. Furthermore, [16] stated that the legal reasons for OHS encompass preventive, punitive and compensatory effects of regulations that protect employees' safety and health related issues at work. Hence, the desire of every organisation is to improve upon the health and safety of its workers.

Engagement as a construct gained popularity after the seminal work of [20]. Kahn defined engagement as "the harnessing of organisation members' selves to their work roles…" (p. 694). Thus, when employees are engaged, they bring all three aspect of themselves – cognitive, emotional and physical – into performing their work roles. The above descriptions of engagement according to [15] show that an engaged employee is intellectually and emotionally bound to the organisation, feels passionate about its goals and is committed to live by its values. Hence, nurses who perceive their workplaces as safe and healthful are more likely to develop a strong sense of passion and involvement in embarking on their assigned task.

Further, empirical findings reveal that OHS management is effective in predicting numerous employee and organisational outcomes. For example, using a sample of 300 woodworkers from a Timber Processing Firm in Ghana, [29] reported a positive nexus between woodworkers willingness to use personal protective equipments and their awareness of safety and health implications on their occupation. Similarly, using a sample of 370 employees from the mining sector in Ghana, [5] found a significant impact of occupational health and safety on affective, normative and continuance commitment. The authors concluded that management within the mining sector of Ghana must recognize the fact that workers, who feel healthy and safe in the performance of their duties, develop emotional attachment and a strong sense of obligation to their organisation and are more likely committed to the organisation. Elsewhere in Spain, [14] found a positive relationship between OHS management and company performance. OHS management has also been reported as a key factor of a firm's reputation and image among its stakeholders [13].

However, despite the aforementioned studies from Ghana and beyond, there remains a gap in the literature on OHS management. A careful review of the literature shows that only a few studies have attempted to examine the relationship between OHS management and employee engagement in sub-Saharan Africa, particularly in the mental hospitals. For example, [26] opined that organisations invest significant efforts and resources to attract and retain proactive and engaged employees; hence, the need for empirical research directed at identifying factors that best promote positive employee attitudes and behaviour in the mental hospitals. Against this background and the identified research gap, we propose the following hypothesis.

H1. Occupational health and safety management is positively related to mental health nurses' engagement.

2.2 Occupational Health and Safety and Turnover Intention

OHS management in the Ghanaian mental health sector has caught the attention of health practitioners and other key stakeholders in mental health due to the low interest among nursing trainees to specialize in psychiatry nursing. This low interest has emerge due to the various work-related injuries and diseases associated with the sector, which present a serious and costly problem to healthcare workers in general. Again, nurses in the mental hospitals also do push for transfers into other areas of nursing leading to a shortage of nursing staff in the mental hospitals in Ghana.

Although some empirical studies on OHS have been conducted in Ghana [e.g., 2, 4, 5, 8, 29], arguably, few of them have examined the relationship between OHS management and employee turnover intention. For instance, in an empirical research in the Ghanaian mining sector, [6] found a negative relationship between the dimensions of OHS management and employee turnover intention. The authors further argued that safety leadership and safety facility were the most significant predictors of miners' turnover and hence concluded that safety leadership in particular was crucial in the administration of OHS in an endeavour to lessen turnover in the mining sector. Besides, [4] opined that OHS encapsulates the mental, emotional, and physical well-being of employees in relation to the conduct of their work and as such represents a vital subject of interest that affects both positive and negative employee and organisational level outcomes. Making working conditions healthy and safe in the mental hospitals is because of the interest of stakeholders particularly employees, employers and government. However, it is imperative to note that the small number of empirical studies linking OHS to turnover intention implies a lack of knowledge in the area and as [30] rightly indicated, a call for more studies is justifiable in investigating the relationship between OHS management and turnover intention in different sectors in sub-Saharan Africa. In line with this clarion call and the absence of empirical research on the OHS-turnover intention nexus in the mental hospitals in Ghana, we propose the following hypothesis.

H2. Occupational health and safety management is negatively related to mental health nurses' turnover intention.

2.3 The Moderating Effect of Job Satisfaction

Job satisfaction has received extensive research attention as antecedent, consequence and a third variable [38]. The earnest desire of every organisation is to encourage improvements in the safety and health of its workers [33] predominantly in an effort to enhance their satisfaction, which implies that an important task of every organisation is to prevent the occurrence of occupational accidents and injuries. For instance, [34] in a study on healthcare workers found a relationship between leading and lagging indicators of OHS and the moderating impact of middle management safety leadership on the direct relations between leading and lagging indicators. Similarly, an empirical study by [13] found OHS management as a major determinant of a company's reputation and its image among the broad stakeholder groups especially employees. Despite the presence of some studies [e.g., 5, 14] in the literature on OHS management, little or no attention has been given to the extent to which occupational health and safety interacts with job satisfaction to influence employee engagement. This study, thus, proposes that proper OHS management policies and practices can increase mental health nurses' job satisfaction, which in turn will influence their levels of engagement within the organisation. Against this backdrop, we formulate the following hypothesis.

H3. Job satisfaction moderates the positive link between occupational health and safety and nurses' engagement.

Furthermore, although the relationship between OHS management and turnover intention has been established mainly in the mining sector, the extent to which job satisfaction has a strong contingent effect on this relationship is yet to be established in the mental hospitals in Ghana. For instance, nurses' perception of the lack of OHS management policies in the mental hospitals is likely to trigger frustration, lassitude and lethargy and finally increase their intention to quit. Research in the healthcare sector has shown that bloodborne pathogen exposure (BPE) which sometimes results from percutaneous injuries (PIs) sustained through needle and other sharp objectives poses a risk of transmission of HIV, hepatitis B and other pathogens to health workers [22, 32]. Similarly, [21] studied occupational exposure to bloodborne pathogens among 1,624 health workers in Botswana. The authors found that 62% of the HCWs perceived themselves to be at high risk for bloodborne pathogenic exposure. Therefore, when these health and safety issues are not properly addressed, it may likely affect the job satisfaction of nurses, which invariably will increase their turnover intention or request for transfer into other sectors in the healthcare sector. In line with the foregoing discourse, we propose the following hypothesis.

H4. Job satisfaction moderates the negative nexus between occupational health and safety and nurses' turnover intention.

3 Method

3.1 Participants and Procedures

This cross-sectional survey drew samples of registered nurses from a large mental sickbay in Ghana. The rationale for selecting nurses as participants is because, from an ethical standpoint, workers have a direct interest in occupational health and safety because they run the major risks of injury if the law fails to protect them. Furthermore, workers often know more about the hazards associated with their workplace than anyone else does, because they regularly work with them [19, 39]. Data were collected from 263 nurses from Accra Mental Hospital. Prior to the data collection exercise, we explained the purpose of the study and assured the nurses that their participation in this study was strictly voluntary and that all identifying information would be removed once the data were coded. In addition, to ensure that we got relevant responses from the nurses, only those who have worked with the hospital for more than six months were eligible to participate in the study.

The demographic data of our respondents show that of the 263 registered nurses, 60.4% were female. In addition, they had an average age of 26.23 years (SD = 3.28) and an average tenure of 4.18 years (SD = 1.98) with the hospital. Furthermore, 72.9% were single and 27.1% married whereas 72.3% of the nurses had obtained at least a certificate.

3.2 Measures

Occupational Health and Safety. Following previous research in Ghana [6, 29], we examined OHS by considering a 6-item, 4-dimension measure. The four dimensions of OHS were measured with [24] 28-item Safety Management Perception Questionnaire. These four empirically distinct dimensions were safety leadership ($\alpha = .78$), safety facilities or equipment ($\alpha = .79$), supervision ($\alpha = .76$) and procedure ($\alpha = .71$). Sample items include "Facilities, equipment and work stations are designed with safety in mind" and "employees are sufficiently trained if safety procedures." Responses were anchored on a 5-point Likert scale from *1 strongly disagree to 5 strongly agree.*

Job Satisfaction. Job satisfaction refers to a pleasurable or positive emotional state resulting from the appraisal of one's job or job experience [25]. A 6-item scale by [1] was used. Sample item included "I am satisfied with my job". The Cronbach's alpha reliability was 0.87.

Employee Engagement. Employee engagement was assessed using ISA Engagement Scale [35]. The ISA engagement scale is a 9-item, 3-dimension measure. The dimensions are intellectual, social and affective engagement. Following previous empirical studies, we combined the dimensions to get a composite score of engagement. Sample items included "I focus hard on my work", "I share the same work values as my colleagues" as well as "I feel energetic in my work". The Cronbach's alpha reliability was 0.85.

Turnover Intention. Nurses' turnover intention were assessed using 3-item scale by [12]. A sample item include "I frequently think of quitting my job". All items were anchored on a 5-point Likert scale ranging from 1 *strongly disagree* to 5 *strongly agree*. The internal consistency score for turnover intention was 0.88.

Controls. Following previous research on engagement and turnover intention [e.g., 6, 15], we controlled for the effect of age, gender and tenure which could account for a variation in the outcome variables.

4 Results

4.1 Confirmatory Factor Analysis

Prior to the hypothesis testing, we conducted a confirmatory factor analysis to verify the fit of our hypothesized model. The fit of the CFA model was evaluated based on chi-square (χ^2) goodness-of-fit test and four other fit indices recommended by [9]. The results of the confirmatory factor analysis show that the hypothesized seven-factor model had an excellent fit to the data (χ^2 (278) = 423.42, χ^2/df = 1.52, RMSEA = 0.04, SRMR = 0.05, NNFI = 0.93, CFI = 0.94, GFI = 0.91). The fit indices indicate a superior fit to the data as compared to the alternative models presented in Table 1. Therefore, the hypothesized seven-factor model was used for the hypotheses testing (Table 3).

4.2 Hypothesis Testing

The hypotheses for the study were tested using hierarchical linear modelling (HLM) analytical technique. To start with, the correlation coefficient as shown in Table 2 depict a significant positive link between safety procedure ($r = 0.29$, $p < 0.001$), safety supervision ($r = 0.18$, $p < 0.01$), safety leadership ($r = 0.36$, $p < 0.001$), safety facility/equipment ($r = 0.28$, $p < 0.001$) and employee engagement. Additionally, a significant negative nexus was found between safety procedure

Table 1. Fit indices for measurement model

CFA model	χ^2	df	χ^2/df	RMSEA	SRMR	NNFI	CFI	GFI
Hypothesized seven factor measurement model††	423.42***	278	1.52	0.04	0.05	0.93	0.94	0.91
Four factor measurement model (OHS; JS; EE; TI)	727.48**	296	2.46	0.07	0.07	0.84	0.78	0.86
Three factor measurement model (OHS; JS + EE; TI)	1020.86**	299	3.41	0.09	0.08	0.76	0.78	0.81
Two factor measurement model(OHS; JS + EE + TI)	1396.86**	301	4.64	0.10	0.10	0.66	0.68	0.76
One factor measurement model (OHS + JS + EE + TI)	1997.24**	303	6.59	0.13	0.14	0.45	0.48	0.69

†† This comprises of occupational health and safety (leadership, procedure, supervision and equipment), job satisfaction, employee engagement and turnover intention.

Table 2. Mean, standard deviation, zero-order correlation among study variables and reliability coefficients

Variables	Mean	SD	1	2	3	4	5	6	7	8	9	10
1. Age	26.23	3.28	–									
2. Gender	0.34	0.32	0.16**	–								
3. Tenure	4.18	1.98	0.39***	−0.07	–							
4. Safety procedure	3.80	0.82	0.04	0.02	−0.01	(0.78)						
5. Safety supervision	3.40	0.66	0.13*	0.13*	0.14**	0.35***	(0.79)					
6. Safety leadership	3.90	0.77	0.13*	0.08	0.09	0.57***	0.49***	(0.76)				
7. Safety equipment	3.49	0.61	0.07	0.01	0.11*	0.39***	0.38***	0.56***	(0.71)			
8. Job Satisfaction	2.01	0.61	0.05	0.03	−0.04	0.18**	0.04	0.12*	0.18**	(0.78)		
9. Engagement	2.58	0. 62	0.05	0.14*	0.06	0.29***	0.18**	0.36***	0.28***	0.28***	(0.85)	
10. Turnover intention	3.01	1.01	−0.07	−0.04	0.09	−0.14**	−0.13*	−0.15**	−0.32*	−0.43***	−0.19***	(0.88)

Note. N = 263; *p < .05; **p < .01; ***p < .001. Internal consistency measures are in (parenthesis) along the diagonal.

($r = -0.14$, $p < 0.01$), safety supervision ($r = -0.13$, $p < 0.05$.), safety leadership ($r = -0.15$, $p < 0.01$.), safety facility/equipment ($r = -0.32$, $p < 0.05$) and turnover intention. Again, mental health nurses job satisfaction was positively related to their engagement ($r = 0.28$, $p < 0.001$) and negatively related to their turnover intention ($r = -0.43$, $p < 0.001$). Finally, a significant negative nexus was found between engagement and turnover intention ($r = -0.19$, $p < 0.001$).

Regarding engagement model in Table 3, the HLM shown that after age, gender and tenure were controlled for, safety procedure ($\beta = 0.13$, $p < 0.05$), safety leadership ($\beta = 0.24$, $p < 0.01$), and safety facility/equipment ($\beta = 0.11$, $p < 0.10$) contributed significantly to explaining 17% of the variance in mental health nurses engagement. However, safety supervision did not contribute any significant effect on employee engagement ($\beta = 0.04$, $p > 0.05$). Besides, when job satisfaction was introduced into

Model 3, only safety leadership was a strong determinant of engagement ($\beta = 0.25$, $p < 0.001$) and accounted for 21% of the variance in the engagement model. Hence, Hypothesis 1, which sought to examine the relationship between the dimensions of OHS and nurses' engagement, was partially supported. Hypothesis 2 stated that OHS is negatively related to turnover intention. We examined this hypothesis using HLM approach. Regarding the turnover intention model in Table 3, the HLM result showed that neither of the dimensions of OHS had a significant effect on nurses' turnover intention. However, when job satisfaction was introduced into the model, safety supervision ($\beta = -0.10$, $p < 0.10$) and leadership ($\beta = -0.41$, $p < 0.05$) were deemed as strong determinants of turnover intention. Thus, Hypothesis 2 was partially supported.

Again, we examined the moderating effect of satisfaction on the nexus between the OHS and engagement. Concerning employee engagement model, job satisfaction had a significant effect on nurses engagement ($\beta = 0.22$, $p < 0.001$). However, the interaction effect of job satisfaction and OHS had no significant effect on engagement. This implies that job satisfaction had no contingent effect on the relation between OHS management and engagement. Therefore, Hypothesis 3 was not supported. Similarly, regarding the turnover intention model in Table 3, the HLM results under Model 3

Table 3. Hierarchical linear modelling for employee engagement and turnover intention

Variables	Employee engagement model				Turnover intention model			
	Model 1 β	Model 2 β	Model 3 β	Model 4 β	Model 1 β	Model 2 β	Model 3 β	Model 4 β
Controls								
Age[a]	−.01	−.04	−.06	−.05	−.12*	−.11†	−.08	−.05
Gender[a]	.14*	.13*	.12*	.13*	−.01	.01	.02	.02
Tenure	.07	.06	.07	.08	.13*	.15*	.12*	.12*
Predictors								
Safety procedure		.13*	.10	.05		−.06	.01	−.14
Safety supervision		.04	.03	.01		−.07	−.10†	−.11
Safety leadership		.24**	.25***	.45*		−.04	−.05	−.41*
Safety facility/equipment		.11†	.07	.16		−.07	.01	−.13
Moderator								
Job satisfaction (JS)			.22***	.53			−.41***	−.25
Interaction terms								
Procedure × job satisfaction				.28				−.27
Supervision × job satisfaction				.03				−.38†
Safety leadership × job satisfaction				.42				−.94**
Equipment × job satisfaction				.21				−.24
R2	.02†	.17***	.21***	.22	.02†	.05*	.21***	.21*
ΔR2	.02+	.15***	.05***	.01	.02†	.03*	.16***	.03*
F	2.49†	9.33***	10.94***	7.47***	2.22†	2.59*	11.03***	8.39***
df	3,330	7,326	8,325	12,321	3,330	7,326	8,325	12,321

Note. N = 263. †p < .10; p < .05; **p < .01; ***p < .001. Reported regression coefficients are standardized estimates only
[a]1 = male; 0 = female

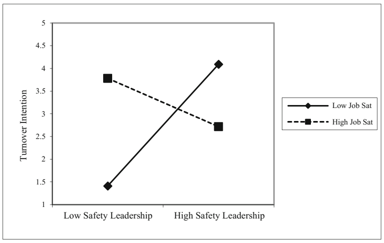

Fig. 1. Interaction effect of safety leadership and job satisfaction on turnover intention

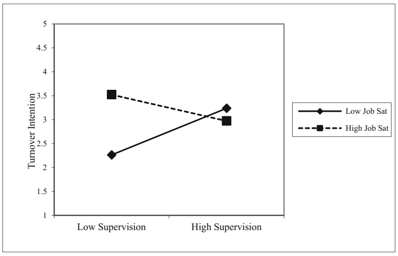

Fig. 2. Interaction effect of supervision and job satisfaction on turnover intention

revealed that job satisfaction had a significant effect on turnover intention ($\beta = -0.41$, $p < 0.001$). Again, under Model 4 of the turnover intention model, job satisfaction has a strong contingent effect on the link between safety supervision ($\beta = -0.38$, $p < 0.10$) and leadership ($\beta = -0.94$, $p < 0.01$) and turnover intention. The amount of variance explained by the interaction effect was 3% in turnover intention. Hence, hypothesis 4 was partially supported. Figures 1 and 2 present the results of the plotted interaction effect. Following [3], we conducted a simple slope analysis to show that nurses' perception of safety supervision and safety leadership are negatively linked to their quit intention when their job satisfaction has a strong positive effect.

5 Discussion

The primary objective of this study was to examine the relations between occupational health and safety management, employee engagement and turnover intention in the mental hospitals in Ghana. Additionally, the study also looked at the extent to which mental health nurses job satisfaction moderate the already mentioned relationship. Despite the fact that some empirical studies have focused on OHS management in the oil and gas sector [8], timber-processing sector [29] and mining sector [5] in Ghana, our paper set out to be among the first empirical studies to examine OHS within the mental health sector. Next, results of our study revealed that safety procedure, safety leadership and safety equipment were significant predictors of mental health nurses engagement in Ghana. However, among these dimensions, safety leadership was the most significant determinant of mental health nurses engagement. This finding is consistent with [6] who reported similar findings in the mining sector in Ghana using turnover intention as their outcome.

Furthermore, results of the HLM showed safety supervision and safety leadership as strong determinants of nurses' turnover intention when job satisfaction was high and vice versa. Finally, our result highlights the relevance of job satisfaction in the nexus between safety leadership and safety supervision, and turnover intention. Hence, with appropriate OHS management policy in place that promotes positive working environment to safeguard employees from sustaining injuries and illness at the mental hospitals, mental health nurses will be unwilling to quit their organisation.

5.1 Practical Implications of the Study

This study highlights safety leadership and supervision as the most predominant predictors of employee engagement and turnover intention. It is imperative to indicate that establishing OHS management policy alone cannot address the health and safety issues in the mental hospitals in Ghana because the sector requires the need for increased efficiency, quality management and effectiveness of OHS management [10]. For instance, the positive linkage between safety leadership and supervision and employee engagement illustrates that promoting an OHS policy through proper monitoring and supervision will strengthen and energize mental health nurses to work hard towards achieving the goals of the hospital. To this end, [7] emphasized that engagement occurs naturally when the wellbeing and safety of workers are the topmost priority of management in the organisation.

Based on social exchange theory, when leaders demonstrate genuine care and attention for the health and safety of employees, they are more likely to improve their sense of belonging to the organisation. Hence, management of the mental hospitals in Ghana should pay specific attention to safety leadership and supervision of health and safety issues of their nurses since engaged nurses are intellectually and emotionally bound to the hospital, feels passionate about its goals and are committed to live by its values.

Furthermore, understanding OHS management and turnover intention in the mental hospitals is imperative since mental health nurses willingness to quit the organisations has both direct and indirect cost and efficiency implications. Promoting a good OHS policy is an important way to increase workers perceptions of the organisation's approach to safety and wellbeing and thus reduce their turnover intention. This implies that a good OHS management can reduce workplace injury rates as well as employee turnover intention. Moreover, most accidents and injuries at the mental hospitals are because of exposure to risk and equipment failure. All of these largely do affect productivity, talent management and retention of employees in the mental hospitals. Poor safety leadership in occupational health and safety management will increase nurses' turnover intention. Therefore, management in the mental hospitals should engage in attitudes and behaviours that promotes the safety and wellbeing of its workers.

5.2 Limitations and Future Research Direction

This research is not without some limitations. Firstly, the small sample size makes it practically difficult to generalize the results, and this may have influenced the results. The above notwithstanding, the sample size was representative of the mental health sector in Ghana. Secondly, we were unable to establish causality due to the cross-sectional nature of the data. The study could not examine whether mental health nurses perception of the existence of suitable OHS management policy causes them to be physically, psychologically and emotionally engaged or less likely to quit their organisation. Furthermore, the paper relied on self-report measures for the data collection, which might result in the issue of common method bias. The direction for future research is to focus on this line of research by exploring other potential moderating variables on the effect of occupational health and safety (OHS) management on engagement and turnover intention in other sectors in Ghana as well as the sub-region. Again, this study analysed the moderating role of job satisfaction on the nexus between OHS management and employee engagement and turnover intention. However, empirical evidence shows that OHS management affect other outcome variables such as affective commitment [5] and job performance [10]. Therefore, future researchers could look at the extent to which OHS management does influence both affective commitment and job performance in the psychiatry hospitals with responses from not only nurses but also administrators, medical doctors and laboratory technicians. Finally, researchers can also establish the causality between the variables used in our model by adopting more statistically robust and rigorous analytical techniques.

6 Recommendations and Conclusions

This study examined the moderating effect of job satisfaction in the relationship between OHS management and work outcomes such as engagement and turnover intention in the mental hospitals in Ghana. Results of the study show that safety leadership and supervision were strong determinants of mental health nurses engagement. It was further observed that an absence of a comprehensive OHS policy or law in Ghana has resulted in a laissez-faire attitude and an unwillingness to go the extra mile as mental health nurses may not be appropriately compensated for certain injuries or risks in the absence of clear guidelines or policy. There is therefore the need for the enactment of an OHS policy or law backed by an efficient enforcement and compliance mechanism to empower management to safeguard employees from exposure to accidents and injuries in the workplace. By so doing, it will enhance the physical, cognitive and emotional commitment of nurses in the mental health sector. Our descriptive cross-sectional study specifies that the social exchange theory may be a suitable framework for OHS management especially in the mental health sector. Furthermore, job satisfaction was a salient construct in that it had a strong contingent effect on the relationship between OHS management and turnover intention. Thus, the more satisfied mental health nurses are with the health and safety policy of their hospitals, the less likely they are to leave their workplace and vice versa. In conclusion, this is the first study to examine the moderating effect of mental health nurses' job satisfaction on the relations between OHS management dimensions and engagement as well as turnover intention in the mental hospitals in Ghana.

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Noninvasive Estimation of Lumber Disk Load During Motion to Improve the Posture

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Abstract. In order to reduce the load by improving the posture, it is necessary to know the load to the lumbar intervertebral disk when patients are in various motions. In this study, we propose a method to noninvasively estimate the load of the lumbar disc during motion. In the proposed method, we consider that the change in the gap between the vertebrae due to the posture change is determined only by the deformation of the intervertebral disc. And the internal changes are estimated indirectly by measuring the shape of the lumbar part from outside the body. And the deformation of the disc is estimated with this, and it will be evaluated as an intervertebral disc load. In this study, a disc load of sneezing motion was estimated and the load on lumber intervertebral disk during motion could be estimated with the proposed method.

Keywords: Lumber pain · Intervertebral disk load · Posture improvement · 2-order approximation · Sneeze

1 Introduction

Due to changes in the working environment and living environment, patients who complain of low back pain have been increasing not only in Japan but also worldwide. There are various kinds of low back pain, but our study group focuses on intervertebral disc herniation. Intervertebral disc herniation is caused by movement of vertebrae due to aging and changes in posture, and then the intervertebral disc will be collapsed. As a result, the intervertebral disk that plays a role of cushioning material between the vertebra and the vertebra is deformed, and a part of the tissue jumps out and presses the nerve, resulting in pain and numbness. It is considered that a cause of pathogenesis of low back pain such as intervertebral disc herniation in daily is repeatedly performing heavily loaded motions on the lumber such as coughing, sneezing and holding heavy objects. Therefore, in order to reduce the load by improving the posture, it is necessary to know the load to the lumbar intervertebral disk when patients are in various motions. And we can prevent the low back pain in everyday life.

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Nachemson [1], Swedish orthopedist proposed method to measure the intervertebral disc load. In this method, a pressure sensor is directly inserted into the intervertebral disc between the third lumbar vertebra and the fourth lumbar vertebra, and the pressure applied to the intervertebral disc is measured. The result shows that the load of the intervertebral disc is larger when the body is tilted forward than the normal standing posture. In this measurement method, it is possible to measure with high accuracy even during motion because the pressure sensor is directly inserted in the intervertebral disc. However, this method lacks safety because it involves surgical operations and may hurt the body. In many other studies [2–5], the joint moment, muscle tension, stress and others are calculated as an intervertebral disk load from the balance of unstable force as an external force to the lumbar part by applying reverse dynamics based on a rigid body link model. In the rigid body link model, the vertebrae is considered as a rigid body and an intervertebral disc is considered as spring and a damper. But it is difficult to reflect accurate information on actual characteristics of parameters which are important in calculation and estimation. And it is difficult to secure high accuracy because many assumptions and constraints can't be used excluding nonlinearity and anisotropy and partial modeling can't consider the influence from the whole body.

In our study group, we estimate the gap between the vertebrae by considering direct movement of the lumbar part without using a process that is an unclear factor. As mentioned above, the vertebrae are sufficiently rigid compared to the intervertebral disc, so they can be regarded as rigid bodies. Also, the position of the spinous process rearmost portion and its movement can be identified on the back surface because the spinous process rearmost portion is close to the back surface and only the thin skin is present between the spinous process rearmost portion and the outside. For this reason, we have proposed a method [6, 7] to evaluate the load on the intervertebral disc by measuring the movement of vertebrae constituting the lumbar vertebra in a noninvasive method from the outside, estimate the gap between the vertebral bodies from the movement. As described later in Chapter 2, the lumbar part has a curvature. In this study, the load of the posture during motion is estimated by curve-fitting the shape of the lumbar part to a quadratic function. In this study, we propose a load estimation method for behavioral posture that can occur in daily life except for postures with holding heavy objects. In this proposed method, this time we will consider whether load can be estimated in sneezing as a posture during motion. We will also examine the effect of the method to reduce the load on the lumber part, which is recommended in medical institutions. In the past study about sneezing [8], sneezing behaviors are investigated by calculating expiration.

2 Method

Figure 1 shows the structure of the human spine. The human spine is a loose S-shaped curve when viewed from the side. The human vertebra consists of the seven cervical spines, the twelve thoracic vertebrae, the five lumbar vertebrae, the sacrum where five are fused and so on. Also, the thoracic spinal system is loosely bent toward the dorsal side (kyphosis) and the lumbar vertebral system is loosely bent toward the ventral side (lordosis). Because of this curvature, we can weaken and balance the shock when walking or running. The spine has an elastic force like a spring as a whole because it has a well-balanced curve in this way. The load on the lumbar part becomes large when this curve disappears due to various actions etc.

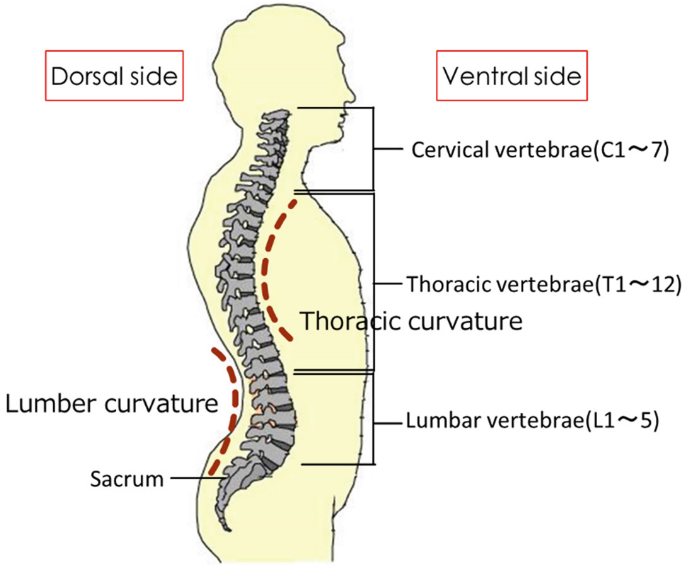

Fig. 1. Spinal structure

Figure 2 shows an enlarged view of the lumbar system. The gap between the vertebral bodies on the front side (ventral side) or the rear side (dorsal side) changes when the posture changes, the vertebra moves, and the intervertebral disc is deformed. In this study, the change in the gap between the vertebrae due to the posture change is determined by the deformation of the intervertebral disc only. Relative load on the intervertebral disc can be derived if we know the change of the gap between the vertebrae when the posture changes. In this study, the vertebra is regarded as a rigid body because it is harder than the intervertebral disc, and we focus on the fact that the vertebrae end exists near the body surface of the back. And we assume that the facet joint of each vertebra is a pin joint and ignore elastic deformation. Then, the radius of curvature is derived by curve-fitting the lumber part to the quadratic based on the position coordinates of the vertebral ends measured from the body surface. In the case of laborless standing posture, the radius of curvature is small and the gap between the vertebrae becomes wide because the lumbar part is lordotic, and it has a curvature. Therefore, the load on the intervertebral disc becomes small. However, the curvature of the lumbar part decreases and the lumbar part becomes straight when the posture changes due to the forward inclination of the body. And, the load becomes large because the radius of curvature becomes large and the gap narrows. It is possible to estimate the load applied to the intervertebral disc by using the radius of curvature because there is such a relationship between the curvature radius and the change of the gap between the vertebrae.

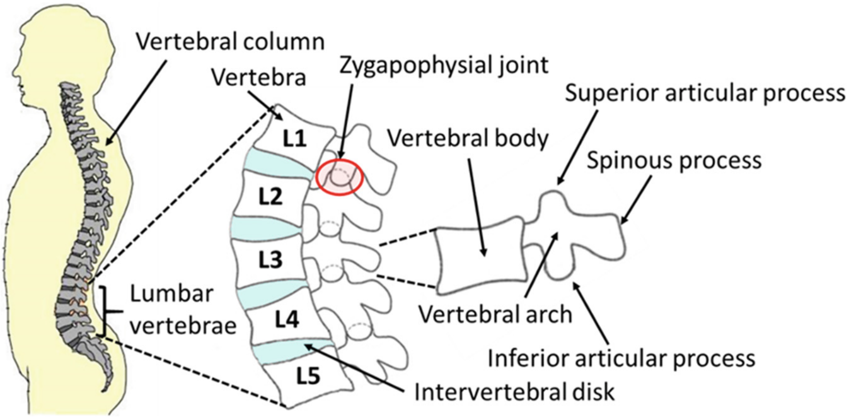

Fig. 2. Lumbar system [6]

We describe a method to derive the radius of curvature by approximating the lumbar part with a quadratic function. Considering the lumbar vertebra as a beam, the approximated quadratic function can be regarded as a deflection curve. Therefore, if the radius of curvature is ρ, a quadratic function is y(x), the radius of curvature ρ can be derived by the Eq. (1).

$$\frac{1}{\rho} = -\frac{d^2y(x)}{dx^2}. \tag{1}$$

From the Eq. (1), the radius of curvature in the lumbar part can be derived because the right side is a constant. The average change of the gap between the vertebrae is estimated from the change in the overall posture of the lumbar spinal system by using the radius of curvature thus obtained. From this change of the gap, the load on the intervertebral disc can be derived.

Among many methods of measuring the lumbar vertebrae of the body surface, we use following. In this study, as shown in Fig. 3, a marker is pasted on the skin from the position presumed to be the end of the vertebra of the back and photographed with motion capture and obtain the position coordinates of the marker. The radius of curvature of the lumbar part can be obtained from the Eq. (1) by curving-fitting the position coordinates of the markers of five lumbar part among the position coordinates of each marker to a quadratic function. Once the radius of curvature is derived, load estimation can be performed by the method [6] which will be described below.

Estimated gaps between vertebral bodies using radius of curvature r. Figure 4 shows the posture change in two dimensions on the sagittal plane of the lumbar vertebra consisting of vertebrae. The load estimation method is described in the case the lumbar part is the lordosis as shown in Fig. 4. A one-dot chain line in Fig. 4 indicates a curve passing through the joint portion (vertebral joint) of the vertebra. d_i is the distance from the position of the joint part to the center of the marker, e_i is the distance from the joint position to the center position of the intervertebral disc (= center position of the vertebral

Fig. 3. Marker pasting position

body) and r is the radius of the arc. We consider that d_i and e_i are constant for every vertebra and use average value. And we consider that d_i is d and e_i is e. Also, it is assumed that the position where the straight line connecting the markers from the center of the circular arc intersects with the vertebra does not change due to posture change. w_i is width of vertebral body i at the intervertebral disc center position. And we consider that w_i is constant for every vertebra and w_i is w. v_i is the length of the vertebra i at the joint position and similarly v_i is v. w and v are constant even if the posture changes because we assume that the vertebra other than the joint portion is regarded as a rigid body and the elastic deformation of the joint portion is ignored.

With this assumption, r_v is defined from Eq. (2).

$$r_v = r + d. \tag{2}$$

As shown in Fig. 4, angle θ_v corresponding to one vertebra is obtained from Eq. (3) using r_v and v.

$$\theta_v = 2\sin^{-1}\left(\frac{v}{2r_v}\right). \tag{3}$$

This equation shows that as the radius of curvature decreases, the angle increases and the gap in the vertebral body widens, which means the compressive force decreases. Conversely, as the radius of curvature increases, the angle decreases and the gap in the vertebral body which means that the compression force increases.

r_w is defined from Eq. (4) in order to calculate the gap quantitatively.

$$r_w = r + d + \mathrm{e}. \tag{4}$$

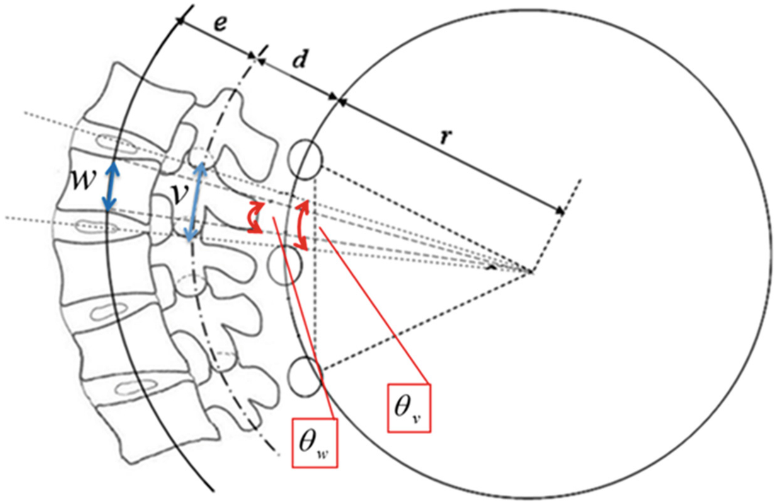

Fig. 4. Parameter on the sagittal plane of the lumbar vertebra (lumbar kyphosis)

And the angle θ_w corresponding to the width w of the vertebral body shown in Fig. 4 is obtained from Eq. (5) using r_w and w.

$$\theta_w = 2\sin^{-1}\left(\frac{w}{2r_w}\right). \tag{5}$$

The angle θ corresponding to the intervertebral disc portion, which is the difference between the two angles, is calculated by Eq. (6).

$$\theta = \theta_v - \theta_w. \tag{6}$$

Further, the result is multiplied by the radius r_w of the intervertebral disc portion and δ is calculated by the Eq. (7).

$$\delta = r_w\theta. \tag{7}$$

δ can be said to be a variable expressing the length of the arc of the gap portion.

If r_0 is the radius of curvature in the unloaded state where no load is placed on the intervertebral disc, δ_0 corresponding to it can be obtained by substituting $r = r_0$ in Eqs. (2)–(7). The change Δδ of the gap from the unloaded state to the measured state in the vertebral body is obtained from Eq. (8).

$$\Delta\delta = \delta - \delta_0. \tag{8}$$

In the simplest case, the load on the intervertebral disc can be represented by the change in the gap multiplied by the spring constant. If δ_0 is the equivalent spring constant for k, the load p can be expressed by Eq. (9).

$$p(\Delta\delta) = k\Delta\delta. \tag{9}$$

In the case of an upright standing position, if the load p is represented by ps with a suffix s it is expressed by the Eq. (10).

$$p_s = k\Delta\delta_s. \tag{10}$$

The normalized load ρ is represented by Eq. (11) when normalized with p.

$$\rho = \frac{k\delta}{k\delta_s} = \frac{\delta}{\delta_s}. \tag{11}$$

In this way, the load ratio can be expressed by a change of the gap.

And, in the case the lumbar part is kyphotic, the signs of r, d and e are reversed because the center of the arc is ahead of the lumbar vertebra. Therefore, if the d is replaced with -d and e is replaced with -e in the equation relating to the estimation process developed in the case the lumbar part is in the lordosis, the estimation process in the lordosis can be used. That is, Eq. (12) may be used instead of Eq. (2) and Eq. (13) may be used instead of Eq. (4).

$$r_v = r - d. \tag{12}$$

$$r_w = r - d - \mathrm{e}. \tag{13}$$

3 Experiment

3.1 Overview

We investigate whether load estimation is possible by this proposed method in posture during motion. In this study, we estimate the load of the sneeze motion as the posture during motion. Sneezing becomes a heavy burden for patients with low back pain, and it also causes the onset of low back pain. Therefore, assuming that reducing the burden on the waist when sneezing will prevent low back pain, and we estimate the load when sneezing with the hand on the wall. This method is also used in the clinical setting. As the experimental method, we paste the 6 mm-markers at twenty vertebral ends on the skin, they are two lower parts of the cervical vertebrae, twelve thoracic vertebrae, five lumbar vertebrae and one upper sacrum as shown in Fig. 3. And the position coordinates of the marker is obtained by photographing with using six motion capture. The sampling frequency in this experiment is 100 Hz, and 6 Hz filter processing is performed on the data on the position coordinates of the obtained marker. The position coordinates of markers of five lumbar vertebrae are used to estimate the intervertebral disc load.

In this experiment, we video recorded for 8 s. And three male subjects in 20's were asked to sneeze twice at standing posture, first time was usual sneezing and second time was sneezing while holding hand against the wall as the prevention posture. The subject experiment was approved by the Kochi University of Technology Ethics Review Committee.

3.2 Result

Not only intervertebral disc load but also acceleration was derived in order to know the body movement during sneezing. Acceleration is obtained by second order differentiation of the position coordinates of the marker. This time, the acceleration in the x axial direction (front and back direction) and the y axial direction (vertical direction) of the marker of the sixth cervical vertebra, which is the marker closest to the head, was derived. Figure 5 shows the acceleration during sneezing motion and the estimation result of the load of one subject when sneezing and sneezing while holding hand against the wall.

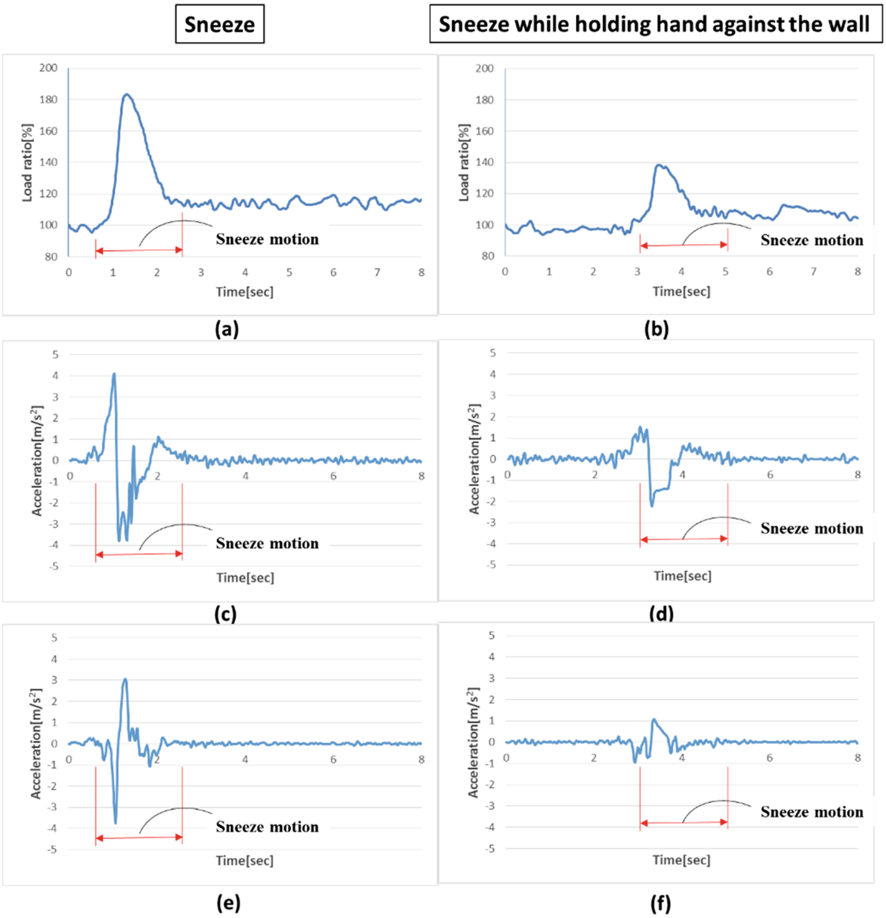

Fig. 5. Estimated result of load and acceleration at sneeze

The graph (a), (c), (e) in Fig. 5 show the result of the usual sneeze, and the graph (b), (d), (f) show the result of sneezing while holding hand against the wall. (a) and (b) show the intervertebral disc load normalized with the load of the standing posture immediately after the start of measurement taken as 100, and expresses the load ratio at each elapsed time. (c) to (f) represent the acceleration, (c) and (d) the acceleration in the x-axis direction (front-rear direction), and (e) and (f) the acceleration in the y-axis direction (vertical direction). Also, in (c) and (d), the forward direction and in (e) and (f), the upward direction are positive. The subject sneezed in about 1.5 s in the graph (a), (c), (e) and sneezed while holding hand against the wall in about 3.5 s in the graph (b), (d), (f).

It is understood that the load in (a) and (b) increased at the time of sneezing. And it is understood that the load when sneezing while holding hand against the wall is smaller than the usual sneezing. Likewise, for the other two subjects, the result was that the load when sneezing while holding hand against the wall was smaller. It is understood that the accelerations in (c) to (f) also increased at the time of sneezing. And it is understood that the acceleration when sneezing while holding hand against the wall is smaller than the usual sneezing.

3.3 Consideration

We found that the change in posture is related to the large intervertebral disc load during sneezing. In the graph (a), the time when the load was the largest was 1.32 s. And Fig. 6 shows the state of 20 markers pasted to the back of the initial posture and in this 1.32 s. In the figure, the left is the dorsal side and the right is the ventral side. And, five markers with red color are markers of five lumbar parts. The horizontal axis of the figure, the x-coordinate is the front-rear direction, the vertical axis, and the y-coordinate is the vertical direction.

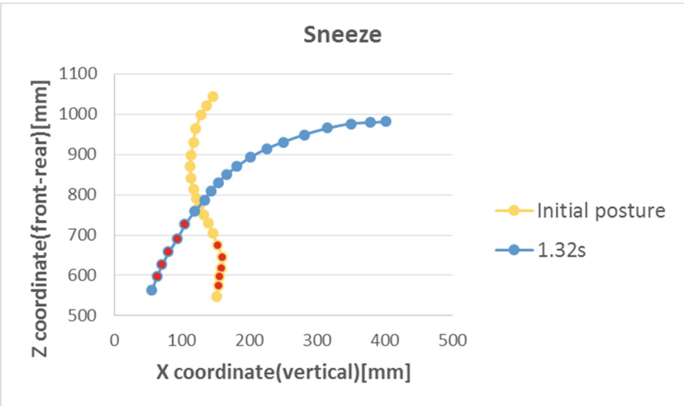

Fig. 6. State of the marker at the time of sneezing motion

From Fig. 6, it shows that the posture greatly changed when the greatest load compared to the initial posture, and the entire spine is not S-shaped. Focusing on the lumbar part, it can be seen that the lumbar part in initial posture is the lordosis, whereas at the time the load is the largest, it is the kyphosis. Experiments performed by

Nachemson have shown that the load is small in the standing posture. It can be seen from the initial posture of Fig. 6, the lumbar part is lordosis and the entire spine is S-shaped at the standing posture which is the small load. And it is considered that the load is large when sneezing because lumber part becomes kyphosis, the entire spine is not S-shaped, the curvature of the lumbar part decreases, the radius of curvature increases, the intervertebral disk collapses and the gap between the vertebrae narrows.

Next, thinking about having reduced the load at the time of sneezing by holding hand against the wall. It is considered that the angle of forward tilt of the body at the time of sneezing is related to a factor of the difference the load size when sneezing and sneezing while holding hand against the wall. Figure 7 shows the state of 20 markers pasted to the back at the time the largest load when sneezing and sneezing while holding hand against the wall.

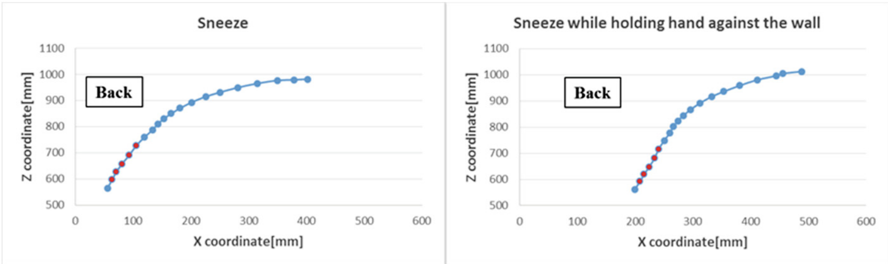

Fig. 7. State of the marker at the time of the heaviest load during sneeze motion

It is can be seen that the angle of leaning forward when sneezing is larger than when sneezing while holding hand against the wall. From this, it can be considered that the load becomes smaller than the usual sneezing by holding hand against the wall because the angle of forward inclination of the body at the time of sneezing becomes small and the curvature of the lumbar part is kept. Focusing on the markers of the five lumbar vertebrae, in the left figure, it is kyphosis, whereas in the right figure, it is lordosis. And, in the left figure, the marker pasted from the cervical vertebra to the sacrum is like one arc. In general, the thoracic vertebra is kyphotic, the lumbar part is lordotic, and the whole spine is depicting a gentle S shape. And, It is considered that the load became large by collapsing the intervertebral disk and becoming the gap between the vertebrae narrow because the radius of curvature of the usual sneezing in which the entire spine is an arc becomes larger than the sneezing while holding hand against the wall in which the lumbar part remains the lordotic.

4 Conclusion

In this study, we proposed the method to noninvasively evaluate the load on the intervertebral disc by measuring the shape of the lumbar part from the outside indirectly and estimating the change of the intervertebral disc. And, the load on the intervertebral disc was estimated by deriving the radius of curvature by curve-fitting the body surface shape of the lumbar part to a quadratic function because the lumbar part depicts a curvature.

In this paper, an estimation experiment of the intervertebral disc load during motion was performed. The load of sneezing motion as a posture during motion was estimated. From this experiment, it was obtained that the load in the sneezing time zone became large, and the load when sneezing while holding hand against the wall was smaller than the usual sneeze. The posture of the entire spine and acceleration during the sneezing motion were derived to investigate the factors that resulted in such a result. As a result, it was understood that the forward angle of inclination and acceleration of the body at the time of sneezing are reduced by holding hand against the wall. Therefore, discussion with the clinic is necessary, but as one of methods to reduce the load on the lumber when sneezing, we consider that it could be quantitatively shown that a method of sneezing while holding hand against the wall by this proposed method is effective.

From the above, the load on lumber intervertebral disk during motion could be estimated with the proposed method.

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Safety and Prevention Management

Mining Traffic Data for the Development of an Accident Warning Application for Tourists

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Abstract. Tourist drivers belong to a category of drivers that are more vulnerable to road accidents due to their unfamiliarity of the road network at a destination. This paper presents a method followed to develop a tool that alert tourist drivers of their accident risks based on situational factors obtained from mobile phone sensors and knowledge distilled from historical records of traffic accidents. The knowledge necessary for the development of a context aware mobile accident warning application was extracted from a spatiotemporal analysis of historical accidents data, to identify patterns of conditions that lead to accidents. Results from this analysis were used to develop heuristics rules that were programmed in a mobile application. The developed system warns travelers of possible threats on the road network of Nicosia, given driver's location and situational factors. The system aims to improve tourists' safety.

Keywords: Accident prediction · Self-organizing maps · Tourist safety · Association rules

1 Introduction

About 1.25 million people die each year because of road traffic crashes and millions more are seriously injured [6]. Among these casualties a high percentage are tourists. Increase in tourism related activities yielded increased tourism-related casualties, with vehicle crashes being the most common cause among tourists' injuries [14]. According to the literature, vehicle crashes is the most common cause of injury for tourists [3–5, 10]. Tourist drivers most of the times are not aware of possible or even known road-hazards, and hence are more vulnerable to accidents. Poor knowledge of the road network and local traffic rules, in combination with insufficient driving skills increase accident risk [15]. Therefore, tourists could have an increased likelihood for traffic accidents [14].

From a data mining perspective, there is a number of approaches to accident detection and prediction. These can be divided into: predictive and descriptive techniques [16, 26]. Descriptive techniques looks at historical data for insight, while, predictive use models and forecasting to understand the future. Some descriptive techniques use cluster analysis to divide heterogeneous data into several homogeneous classes or clusters [17]

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and subsequently find patterns in these classes. This paper presents a combination of descriptive and predictive analysis of historical traffic accidents, occurred between 2004 and 2014 in Cyprus, to identify black spots using SOM Artificial Neural Nets (ANN) on the road network and subsequently distil patterns within each black spot. The heuristic rules that were mined from the patterns are utilized for the development of a mobile accident warning application to alert tourist drivers of imminent risks. The application utilizes prior knowledge, in combination with real time situational factors obtained from the tourist's mobile device sensors.

The paper is organized as follows. Firstly, a review of the literature is presented followed by an overview of the methodology. Subsequently, the steps followed to clean and pre-process the accident data are explained, along with the application of a SOMs. The underlying theory of SOM is presented and the SOMs' results are explained. Next, the application of association rules to identify patterns in each cluster is described and the use of the elicited heuristic rules for the development of a mobile application for tourists. The paper concludes with a summary and future directions.

2 Related Work

A significant amount of research is conducted in the area of accident forecasting using data mining, to invent accurate mechanisms for accident prediction [20]. In our previous work [9] we combined Bayesian Networks with a Dynamic Traffic Assignment Simulator to identify black spots in Nicosia-Cyprus. This paper is a continuation of that work and concentrates on the application of clustering and association rules, for the identification and analysis of accident black spots. Similarly, Sun [8] proposed a method for real-time accident prediction using a Dynamic Bayesian Network (DBN) to handle spatiotemporal time-series crash data in combination with traffic data (speed, flow and occupancy) collected from highways in Shanghai in China. Their DBN achieved a crash prediction accuracy of 76.4% with a false alarm rate of 23.7%.

Clustering methods is a type of Data mining techniques that are important in identifying groups of records which are characterized by common features. Hence, groups items together on the basis of similarities or dissimilarities [22], and has been used extensively for market segmentation [19]. Despite the fact that statistical models have been widely used to analyse road crashes, certain problems may arise when analysing datasets with large dimensions [21]. In such cases data mining is used that extract implicit, previously unknown, and potentially useful information from large amounts of data [23]. When dealing with a large and complex datasets, the use of data mining methods seems particularly useful to identify the relevant variables that make a strong contribution towards a better understanding of accident conditions.

In traffic analysis, applications of SOM include but not limited to, work by [2] that combine cluster analysis, regression and GIS to assess the risk of traffic accidents. Work by Pei Liu [10] also utilize SOM in combination with Data Mining (DM) models to analyse liability attributions of car accidents. Their developed Decision Support Tool uses previous similar crash cases, to assess compensation attributions for insurance companies. Their DM model achieved a 65% accurate authentications for rear collisions and 73% and 82% for frontal and side collisions respectively. The decision support tool they developed, appeared to provide helpful information for similar collision cases. On the same vein, work by Alikhani [11], used a hybrid approach of clustering and classification methods to check if the pre-clustering of data can improve the accuracy for classifying the severity of road accidents. They used K-means and SOMs for clustering and ANN with Adaptive Neuro Fuzzy Inference for classification. Their results showed that pre-clustering improved the results' accuracy. In all combinations of the above methods, the hybrid model accuracy was higher than using individual classification methods, with the highest accuracy being achieved by pre-clustering data using SOM, followed by a classification model using ANN. Another study by Kassawat [12], also engage the problem of identifying potential accident prone locations on a map, based on user input. They developed an interactive web based system that used an integrated Poisson Regression model and a Multi-attribute Decision Making tree based on the Decision Expert approach. The developed system allowed the user to enter weather and time information through an application interface, and produced as output a Google Map depicting points on a map that were at risky. Each point was categorized in 3 levels of risk namely, green for low risk, yellow for moderate and red for high risk. In another related work, Hoon Kwon [13], used data from California Highway Patrol to compare two classification methods, Naïve Bayes and Decision Trees, to reveal the relative importance of the risk factors with respect to accident severity. The Naive Bayes method did not consider dependencies among the risk factors, whereas decision trees did. They used two scoring algorithms to rank the risk factors and their results showed that Decision Trees outperformed the Naïve Bayes model, concluding that dependencies among risk factors are important. Work by Miao Chong [7], compared the performance of ANN, Decision Trees, and Support Vector Machines to predict injury-severity of accidents. Their results shown that combination of machine learning techniques yields better results. Specifically, the hybrid Decision Tree-ANN outperformed the other two approaches.

Based on the literature, it is evident that combination of techniques seems to outperform single method approaches. Hence, the method proposed herein utilizes two machine learning techniques aiming to firstly identify the main clusters of traffic accidents in Nicosia using a combination of input parameters, and subsequently to pinpoint the factors that significantly affect accidents for each cluster. The knowledge distilled from this process was used to develop an accident prediction model that embedded in an application, used to inform tourists of possible accident risks on a real-time basis.

3 Data Analysis Methodology

The purpose of this study was to analyse historical road accidents data from the Cyprus Police, to identify black spots on the road network of Nicosia and subsequently to discover patterns that describe causes of accidents. The methodology followed is diagrammatically depicted in Fig. 1. The main steps in the process include the integration of accident data with traffic flow data from a traffic simulator as per our previous work

[9]. Subsequently, pre-process the resulting dataset to eliminate outliers and reduce the dataset's dimensionality as explained next. Finally perform cluster analysis and association rules extraction on the clusters that emerged. The distilled knowledge was utilized to specify the heuristic rules for the tourist accident warning application decision engine.

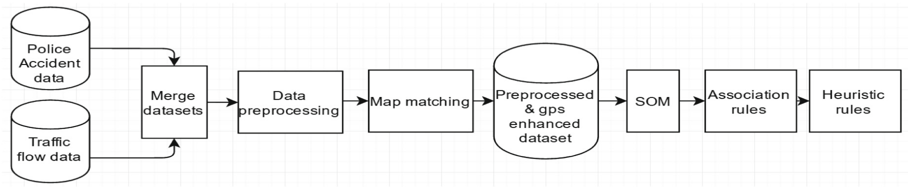

Fig. 1. Methodology

3.1 Data Pre-processing

The original accident dataset contained 21179 accident records occurred in Nicosia, Cyprus between 2004 and 2014. An accident record contains 47 variables, each associated with multiple attributes. The variables are categorized in the following groups: environment, infrastructure, driver and vehicle. Pre-processing and data transformation was performed to reduce the dataset's dimensionality and convert the data in the desired format based on the rules of Table 1. These rules have been specified by a traffic safety expert. The study focused on the town of Nicosia, hence the data was selected accordingly from the original dataset.

During pre-processing no missing values were identified, but some outliers (extremely high speed and traffic flow) were discovered and were excluded from the dataset. Four accident types were available, namely, fatal, serious, light injuries, and damage-only. The last two types were merged into one, so three types of accidents were used. Accident time was converted into time interval variable as shown in Table 1. Accident-point was only used to identify the geolocation (coordinates) of accidents as described later in map-matching Accident data.

Table 1. Pre-processing rules

Variable name	Variable states
Day	1 for Sunday, 2 for Monday, 3 for Tuesday, …, 7 for Saturday
Time	1 for 11am–1.59pm, 2 for 2–4.59pm, 3 for 5 to 7.59pm, 4 for 8–10.59pm, 5 for 11–1.59am, 6 for 2–4.59am, 7 for 5–7.59am, 8 for 8–10.59am
Factor	1 for mental state of driver 2 for driver inability old fields 8, 10–11, 16–17, 26, 31–33, 35, 3 for carelessness old fields 9, 12–15, 18–25, 27–20, 34, 36–42, 4 for vehicle fault old fields 43–52, 5 for environmental cause old fields 53–66)
Traffic control	1 for none and traffic signs out of order, 2 for stop sign, give way sign and roundabout, 3 for police and traffic signals (both traffic signals and police as well as flashing traffic signals do not appear in the records
Road Width	1 for < 7 m, 2 for 7–10 m, 3 for > 10 m
Diagram code	fields 1–10 car-to-car, namely 1 for nose to tail, 2 for overtake, 3 for frontal, 4 for side, 5 for one car stationary, 6 for angle, 7 for runoff, 8 for object, 9 for other, 10 for pedestrian involved, 11 for other
Junction type	1 for intersection of two or more roads, 2 for T-junction, 3 for staggered junction, 4 for Y-junction, 5 for roundabout, 6 for slip road, 7 for other, 8 for no junction
Barrier	1 for none, 2 for single broken, 3 for single or double continuous single, 4 for island (ghost island, with or without physical barrier), 5 for combination of the above
Road works	1 for yes, 2 for no
Bus stop	1 for yes, 2 for no
Light	1 for daylight, 2 for dawn, 3 for dusk, 4 night-street lit, 5 for night-street unlit,
Road description	1 for straight and flat, 2 for straight and not flat, 3 for curved
Pavement type	1 for good, 2 for bad
Weather	1 for dry, 2 for other
Accident Type	1 for fatal, 2 for serious, 3 for light and damages only
Speed	1 for high 2 for low
Traffic flow	1 for high, 2 for average, 3 for low
Age	1 for < 18, 2 for 18–35, 3 for 36–55, 4 for > 56
Gender	1 for Male, 2 for Female

3.2 Map Matching Accidents to Geolocation

Due to the unavailability of the geospatial coordinates of all accidents', the accident data had to undergo processing and map-matching onto a GIS system. The original dataset as was obtained from the Police, was plotted on a hardcopy map divided into squares and populated with accident locations. Hence, it had to be converted into an electronic form to enable its processing. Specifically, a variable X in the dataset, encoded the X/Y coordinates of the accident on the hard-copy map. The first letter and the subsequent two digits of X corresponded to a square on a map, while the last two digits to the road-link in the matching square, where the accident occurred. To avoid manual entry of each individual accident on the GIS system, accidents were grouped according to the box they belonged based on their XY coordinates. For instance, for an accident with X value of 'M1201', the last two digits were ignored and the accident was assigned a new value of ‘M12’ representing the id of the box on the map. To achieve that, we used Google Earth to geotag the GPS coordinates of each box from the original hard copy version of the map. To do that the two end points of each square were used. The upper left and lower right corner that formed the diagonal of each box. This was done for all boxes on the road network, resulting in the map depicted in Fig. 2. Subsequently, the coordinates were exported from Google Earth in a KML format and imported in ArcMap from where it was again exported in an.xml format and subsequently converted in excel format. In order to make consecutive work easier, we used the coordinates of the midpoint of the diagonal of each square, as the coordinates of each box.

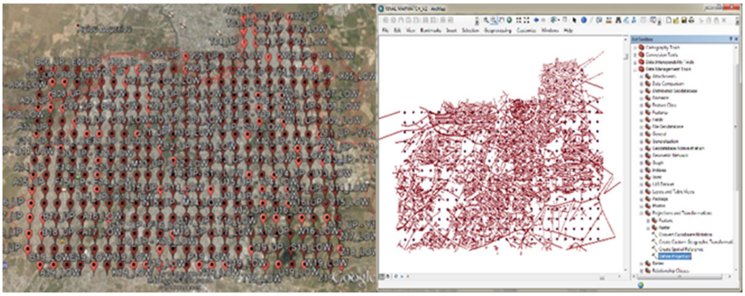

Fig. 2. Map of Nicosia overlaid with tags of centroids of the segmented road network. ArGIS map with cancroids for each accident box (right)

To do this we added the longitude and latitude coordinates that described the two diagonal corners of each square and divided these by 2. This yielded one set of coordinates for each square and for the accidents that falls within that square. Finally, an algorithm was devised in MatLab to assign each data-point from the pre-processed dataset to its corresponding box. Accidents that fallen outside the modelled map boundaries were ignored. The resulting number of accidents modelled using this coordinate system was 13327.

To enhance accident records with traffic flow information at the time of the accident, ArcMap was also used. Essentially, mapping accident location with the road link on a simulation model and from there retrieving the traffic flow for that link at the time of accident. The source was the shape files provided by our previous work [9]. Shape file is a common data file format for GIS software and it is stored as a set of related files. It can spatially describe features like points, lines and polygons that may represent roads, rivers, lakes etc. The graphical representation of the shape file with the overlaid centroids of each of the squares is depicted in Fig. 2.

3.3 Self-organizing Maps

Clustering is used in market segmentation [18] to provide a conceptual view of heterogeneous markets [19]. Numerous clustering methods exist that are divided into hierarchical and partitioning techniques i.e. DBSCAN, Expectation Maximisation, K-means. The latter however was criticised in accurately detecting clusters when these do not have spherical shape [24]. All these techniques lack appropriate visualisation metaphors. On the contrary, SOM provides the analyst with an intuitive visualisation that enables the interpretation of its results. Essentially, SOM is a special case of Artificial Neural Networks used for identifying patterns to cluster data by identifying common features. SOM produces a low-dimensional representation of the input space of the training data, called a map and belong to the category of unsupervised competitive learning algorithms for which, no human intervention is required.

The general idea of a SOM is to take an input matrix N × M of N variables and M occurrences of each variable, and parse it into the SOM topology (usually a two dimensional grid or map). Using a neighborhood function, neurons organize themselves forming clusters on the output SOM topology. In SOM algorithm, the output neurons compete between themselves against the characteristics of an input vector that describe the variables of the problem. Only one neuron is activated at any given time during a SOM process cycle. The activated neuron is called the winning neuron (or Best Matching Unit - BMU). Hence, each occurrence of the variables-set (also called input vectors) is eventually assigned to a cluster. Input vectors that are similar are grouped into clusters on the output SOM topology. To achieve this competition, there are feedback paths between the neurons which in return force neurons to organize themselves. The aim in SOM learning is to cause different parts of the network to respond similarly to certain input patterns.

Each neuron is a node on the network and is associated with a weight vector that describes its similarity to the input vector. Every node of the SOM is examined to identify the one whose weight is most similar to the input vector. The BMU is the most similar to the input vector. The input data X is parsed into an M = [m1, m2] topology as shown in Fig. 3. Each cell of the input vector X(n) is fully connected to all nodes of M. The lines connecting the input vector with the output topology represents a weight vector W(n, k) and have the same dimension as the input vector. W(n, k) specifies the connection weights between the input X(n) and the neurons k in the output topology O(k). Essentially SOM converts a high dimensional input Space X(n) with n input vectors and m Variables into a low dimensional output space (SOM topology) O(k) as illustrated in Fig. 4.

X(n)	Input Variable 1	Input Variable 2	…	Input Variable m
X(1)	Attribute (1,1)	…	…	Attribute (1,m)
X(2)	Attribute (2,1)	…	…	…
…	…	…	…	…
…	…	…	…	…
X(n)	Attribute (n,1)	…	…	Attribute (n,m)

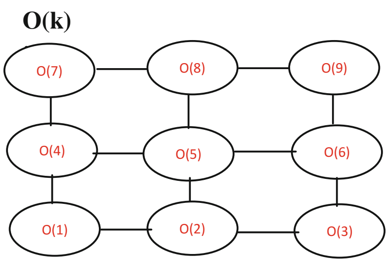

Fig. 3. Representation of input to SOM topology

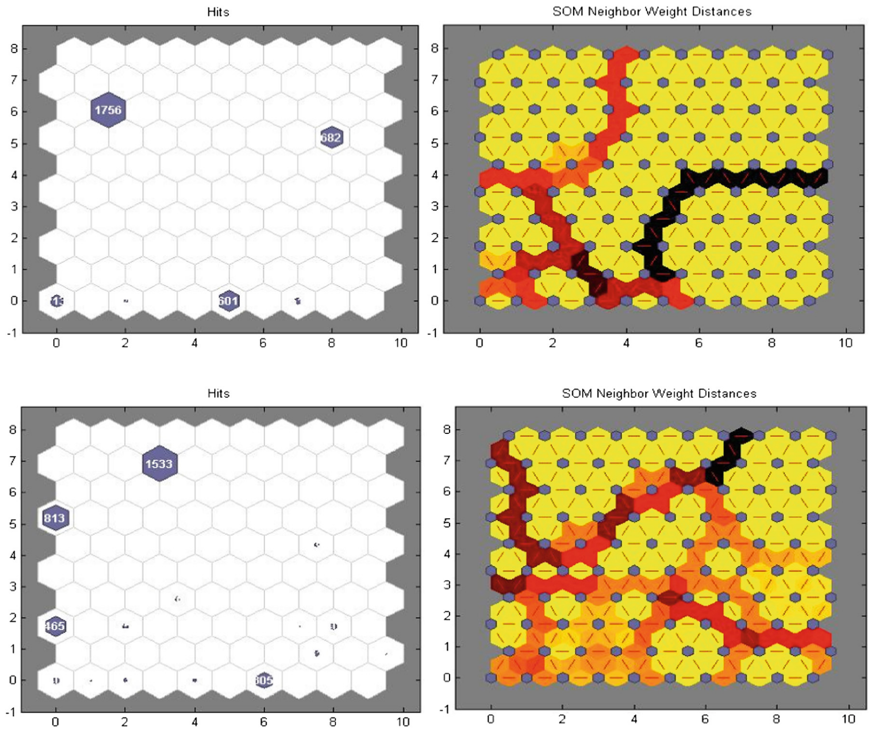

Fig. 4. SOM sample hits plot and neighbour weight distances for accident type and gender (top row) and accident type and lighting (bottom row).

The Input Data is parsed to the SOM topology O (k) as shown below. Each occurrence of the Input Space X (n) is fully connected to all nodes of O (k). The lines connecting the input vector with the output topology represents a weight vector W (n, k) of the same dimension as the input vector that specifies the connection weights between the Input X (n) and the neurons k in the output topology O (k) [13].

The algorithm used in SOM is the following: firstly initialize the connecting weight vectors of neurons with random values. Then, a vector X(i) from the input accident dataset is randomly chosen and presented to the SOM topology. The weights of all neurons of the topology are examined to find the ones that are closest to the input vector-BMU. The neuron which is closest (distance) to the input vector wins the competition. The neighboring nodes' weights are adjusted so that they get closer to the input vector. The change of the weights of the neighboring neurons depend on how close they are to the winning neuron. The process is repeated for number of epochs (iterations) specified by the user. To determine the BMU, the most common method is to calculate and compare the Euclidean Distance of each and every neuron's weight vector and compare it with the randomly selected input vector. The neuron that has the smallest Euclidean Distance from the Input vector is the BMU.

Matlab's Neural Network Toolbox was used to run the SOM analysis on the accident dataset. A 15 × 15 SOM Topology was used to give flexibility to the algorithm to clearly create the desired clusters. The algorithm run for 1000 epochs. All combinations of variables were used during SOM analysis. All variables were specified in accordance to accidents' geospatial coordinates.

A limitation of SOMs is the ability to handle all types of variables the same way. Attributes of numerical and ordinal type can be placed in an ascending or descending order. So, Euclidean distance works fine on these data. That is not the case with categorical data. Categorical data can be grouped but cannot be placed in order. For example hair color. It can take many values: black, brown blond etc. but these values have no natural ordering and no meaningful 'distance' between the categories. So it would not make any sense to assign black = 1, brown = 2 and blond = 3 and pass it into a SOM as input. The reason is that black would be closer to brown and farther from blond which is not the real case. The recommended way to include categorical values in Matlab is to use the 1-of-N encoding [9]. This method transforms the categorical variables into dummy binary indicator variables. For example hair color with attributes black, brown and blonde can be converted as shown in the Table 2.

Table 2. '1-of-N' Encoding

	X1	X2
Black	0	0
Brown	1	0
Blonde	0	1

X1 and X2 are the dummy indicator variables. X1 has value 1 for the Brown category and 0 elsewhere, X2 has value 1 in Blonde category and 0 elsewhere. Black category is represented with the value 0 in both indicators. Together these two dummy variables represent all three categories of black, brown and blonde. In our case, the categorical variables were first transformed using the '1-of-N' encoding as explained above.

To find the combinations of variables that yield significant clusters with regards to accident occurrence, a permutation algorithm was used that created executed a SOM for all possible combinations of input variables and dependent variable Accident_Type. Thereafter, the SOM output plots from each run was analysed to identify the most important sets of variables based on hits and significance plots for further causal analysis.

4 Results

A subset of the clusters that yielded from the analysis are depicted in Figs. 4 and 5. The "SOM Neighbour Weight Distances" depicts the distances between the neighbouring neurons. Grey dots represent the neurons (clusters), while red lines connecting neighbouring neurons and the colours that surrounds the red lines represent how similar a neuron is to its neighbour. Dark colours represent large distances between neurons which indicate dissimilarity and lighter colours represent closer distances which indicate similarity. Continuous lines with dark colours (borders) indicate that the network has segmented inputs into groups of clusters where each group has different features. The

"SOM Hits plot" indicates how many instances (vectors) of the input data are associated with each neuron (cluster centre), as well as the neuron location.

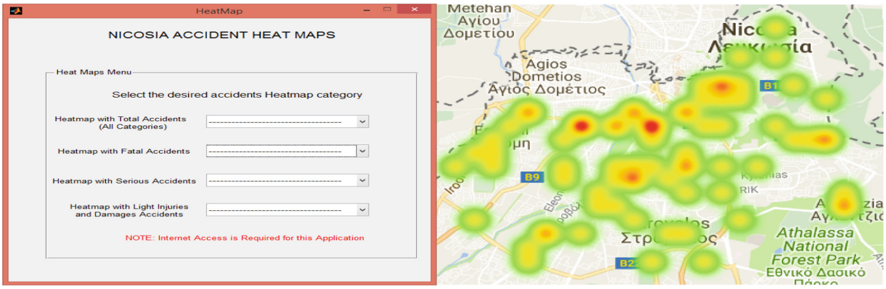

Fig. 5. Heat map for light accidents occurring in Nicosia

Accident Type and Gender, analysis from the 'SOM Sample Hits' plot in Fig. 4, depict 3 large cluster with IDs 6, 69 and 72 having 601, 682 and 1756 hits respectively. The 'SOM Neighbour Weight Distances' plot clearly shows all clusters created. Cluster 6 with 601 hits (18%) represent serious injury accidents in which males were involved. Cluster 69 with 682 hits (20.4%) show light injury accidents in which females were involved. Cluster 72 with 1756 hits (52.8%) show light injury accidents in which males were involved. Also in cluster 1 with 213 hits (6.4%) show serious injury accidents in which females were involved. It is clear that, the number of males involved both in serious and in light injury accidents is nearly three times the number of females.

Accident Type and Lighting analysis from the 'SOM Sample Hits' plot in Fig. 4, depict four large clusters with IDs 7, 21, 61 and 84 with 305, 465, 813 and 1533 hits respectively. The 'SOM Neighbour Weight Distances' plot in Fig. 4 show how the clusters were formed for this SOM. Cluster 7 with 305 hits (9%) show serious injury accidents occurred with night street-lit. Cluster 21 with 465 hits (13.9%) show serious injury accidents occurred with day light. Cluster 61 with 813 hits (24.4%) show light injury accidents occurred in night street-lit. Cluster 84 with 1533 hits (46%) show light injury accidents occurred with daylight. More than half of all accidents of accidents occurred in day light and this supports the results of Accident Type and Accident Time above, where most light accidents occur between 09:00 and 18:00.

5 Patterns Identification

To identify patterns in each black spot, the accident records that belong to each black spot were extracted from the original dataset and stored in separate data-files. Subsequently, an Association rules algorithm was used to identify patterns in each data-file. The main approaches are: Apriori, Eclat and FP-Growth [26]. The association rules algorithm used is the Apriori algorithm [1] since it has been considered the most effective and efficient for finding frequent item [25]. The Apriori algorithm uses the support and confidence measures to generated valid association rules. Support is the percentage of instances of records in the dataset for which a pattern (rule) is true. For example the support for the association rule A->B is the total number of instances containing both A and B divided by the number of total instances of the dataset. Confidence is the level of certainty that describes each discovered pattern. For example the confidence for the rule A->B is the number of instances containing both A and B divided by the number of instances containing A.

The rules that emerged form the association rules, highlight the importance of gender, age, day of the week, time, traffic control, and distractions such as road works, bus stops and bad weather on accident occurrence. Hence, for the black spot in question, the mined rules highlight that, most accidents arise by younger male drivers, at the signalized intersection of the black spot. The effect of bad weather, bus stopping or having to diverse due to road works has also a negative effect on accident risk. Mined rules for each black spot are stored in a rules repository associated with the geolocations of the black spot. The application depending on the GPS location retrieves from the repository the rules that match its coordinates and the characteristics of the driver and present the risk through the user interface. Therefore, drivers that use the application can be warned of different type of accidents that are more likely to occur, given their spatiotemporal, genotype properties, and environmental conditions. At first instance the application does not utilise the driver's speed. This can be easily retrieved from the mobile's build in sensors.

To enhance the validity of the study, mined rules have been confirmed by 2 traffic safety experts that verified their rationality. These rules are used as the basis for the development of a prototype prediction engine of the mobile accident warning system. Essentially, given the characteristics of the driver, such as: age and gender, and in combination with information regarding the day, time, weather conditions and gps coordinates, the application fishes out of its database the rules that apply to that situation and accordingly warns the driver.

6 A Software Application to Supports Tourist Drivers

The main usage of the application is to warn tourist drivers of imminent risk on the road network of Nicosia. The application utilised the build-in capabilities of mobile phones to recognise geolocation and travelling speed, and accordingly in combination with information regarding time and day of the week, analyses the risk and present the user with possible warnings. For the system to be able to warn drivers it was essential to create a spatiotemporal analysis of the black spots on the road network of Nicosia. This prerequisite the development of a temporal heat-map using the historical data as described previously.

For the generation of the accident black spots heat-maps, we utilised the Fusion-Tables tool provided by Google. The pre-processed data was analysed using SOM and the output for each input set was imported into the tool to create a series of heat maps for all combination of variables, for the Nicosia network. Geolocation data was used as input, along with accident related information. The black spots on heat maps are identified using the neighboring distances matrix and hits plot. These designate geographical locations with large number of hits (counts) compared to other locations. The clusters identified with SOM, for all combinations of input datasets, were imported in fusion-tables to create a series of heat maps. Each map was associated with a set of features that describe the situations i.e., age of driver, day, time etc. These associations were used in the developed Matlab application, to visualise the results according to user properties. Specifically, the Matlab Graphical User Interface Design Environment (GUIDE) was utilised to create the application interface. The applications was created in the form of a package and an installation wizard, which enables a third party user to download and install a free Matlab Runtime Environment (MRE), to run the application. An illustration of the interface of the developed application is depicted in Fig. 5, which shows the heat map for young drivers associated with light crashes. Different SOMs, and their associated heat maps are utilised by the application depending on the features entered by the user, regarding the driver characteristics. Properties that refer to the environment are dynamically inferred from the situation such as: the day, time and weather conditions.

7 Conclusions

In this study, we demonstrated the use of SOM for the analysis on traffic accident data, which were then used to identify the black spot for the city of Nicosia. These were subsequently analysed using association rules to identify patterns that were used to specify rules for an application that warns tourist drivers of potential accident risks. For this goal, various tools were used: Matlab's, Weka, ArcGIS, Google earth and Fusion. The output of this analysis was used to develop a prototype application to warn tourist of potential accident risks based on contextual information that could be obtained from GPS coordinates and user's characteristics.

Our future work aims to fully realise the mobile application and integrate its functionality with web services such as weather and temperature, to enhance the contextual information that describe driver's situation. This in combination with the knowledge distilled from this study will provide the means to dynamically calculate the risk of accident occurrence. An evaluation study will follow to assess the effectiveness of the system on tourism safety.

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Driving Workload Indicators: The Case of Senior Drivers

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Abstract. The automotive industry is currently focused in the goal of developing advanced autonomous driving systems (ADAS) and its supporting technologies. A main condition for achieving this goal is to ensure drivers' safety and comfort during the ride. The driving task is often described as complex and dynamic and can be considered as the single most risky task that the individual has to perform on a daily basis. Since the mean age of the population in industrialized countries is gradually increasing, one of the ADAS objective is to enhance mobility of seniors by easing the task of driving to levels with which they are able to comply. This paper aimed at researching present key workload indicators that can be used by the car autonomous driving systems to establish the more efficient means to keep the senior drivers informed about the driving task and surrounding environment, allowing them to benefit from other entertainment applications and safely resume the driving task.

Keywords: Workload · Elderly · Driving · ADAS · Human factors

1 Introduction

Currently, it is easily verifiable that the mean age of the population in industrialized countries is drifting, with the older population becoming more prevalent [1]. According to the database Pordata (2016), the Portuguese aging index in 2015 was 143.9%, which is approximately 5.2 times higher than the one measured in 1961 (27.5%). Glaser and Schubert (2007) also refer that in 2050, and according to the German Federal Office of Statistics, the German population with more than sixty years old will increase from the 24.1%, measured in 2001, to 36.7%. In Japan, already considered the firstsuper-aged" country in the developed world, the elderly were responsible for more than 40% of all traffic fatalities [2].

The automotive industry is focused in developing Advanced Autonomous Driving Systems (ADAS) and its supporting technologies. A main condition for achieving this goal is to ensure drivers' safety and comfort during the ride. The driving task is often described as complex and dynamic and can be considered as the single most risky task that the individual has to perform on a daily basis [3]. Recently, the U.S.A. Department of Transportation (DOT) issued the Federal Automated Vehicles Policy to ensure that these technologies are safely introduced and provide present and future safety benefits [4]. In the Executive Summary of the Federal policy entitled "Accelerating the Next

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Revolution in Roadway Safety", the DOT stresses out that 35,092 people died on U.S. roadways in 2015, and points that 94% of crashes can be tied to a human choice or error. According to SAE's International definitions of levels of automation, in the first four levels (level 0 to level 3), the human driver is responsible for taking back the control of the car, by request of the automated system [5], and in level 4, the automated system can only operate in certain environments and under certain conditions. Therefore, the human driver attention to the driving task and environment must be assured and controlled, or managed, for all these first five levels of vehicle automation. It is generally assumed that the deployment of automated driving will encompass six effects: eliminate or decrease congestion through management of the traffic flow, reduce traffic accidents by avoiding human errors, diminish environmental load through optimization of the traffic flow and reduction of the consumption of fuel, enhance the pleasure of driving by reducing the pressure associated with driving in stressful scenarios, strengthen international competitiveness and, adapt to demographic changes by supporting unconfident drivers and enhancing the mobility of elderly people [6, 7].

In Japan, it has been acknowledged the rise of the percentage of elderly drivers amidst accident fatalities, as well as a pattern of errors committed by this population stratum. Through automated driving it is expected that the workload of these drivers is significantly lowered to levels by which they can better cope with the driving, and traffic problems characteristic of elderly people will be solved [7]. As noted by [8], while the terms stress and workload arise out of somewhat different traditions, there is a great deal of conceptual overlap in describing demands on the individual arising from both internal and external factors. According to Eby, Molnar, Zhang, St Louis, Zanier and Kostyniuk (2014), the risk of engaging in fatal crashes is higher for senior drivers, with an increased involvement in intersection crashes.

Three functional abilities are required from the driver to perform the driving task: cognitive, visual and psychomotor. Even though age is often associated with driving errors, several studies point out that the declines in these functions may arise from age-related medical conditions and medications aimed at treating these conditions [9]. Ultimately, elderly people suffer from specific problems in terms of divided attention performance, which is highly required in driving [10]. Nevertheless, it is a fact that elderly drivers with hearing loss (HL) perform worse while driving with distractors [11]. The effect of HL in driving has not yet been thoroughly researched, with a strand of researchers finding a concomitant effect, while another does not find any relation between the two variables. The use of hearing aids, though, has been reported as being associated with higher risk of accidents [11].

Lawton et al. (2008) refer that the task of driving, which is normally performed in a comfortable position, can be very stressful because of the many different solicitations that may occur. It can be complex because of the lateral and longitudinal forces on the driver during those solicitations, which can bring him out of balance, augmenting the probability of wrong hand placement with the subsequent problem of activating the wrong controls. Bellet et al. (2003) describe the driving task as both complicated and dynamic, considering it as one with the most risks that an individual has to perform daily. But it is interesting to verify that these conditions (daily use and associated risks) seem to contradict each other. As driving is a complex task performed by a large part of the population, which indicates global generalization, should, therefore, be a simple and risk-free task. Yet this idea fades whenever the annual number of car accidents is verified [12].

Advanced in-vehicle technologies help extend the period over which a senior driver can drive safely, by helping older drivers avoid crashes, improve the ease and comfort of driving, and travel to places and at times they would otherwise avoid [9]. Simultaneously, more entertaining applications are being made available for the driver to use inside the car. All things considered, one can assume that these infotainment applications are competing with the attention and awareness of the human driver to the driving task. Ryu et al. (2010) refer that driver information systems require drivers' visual attention for, for example, selecting the desired functions, which in turn can increase the periods in which the driver eye-gaze is set off the road, consequently increasing the probability of accident occurrence. Considering that slowness of behavior is a consequence of ageing [13], it seems reasonable to assume that this additional workload may be dependent of the drivers' age. Moreover, even though one can agree that modern technology has brought improved quality to people's life including older ones, older people often lack the skills to interact and benefit from such technologies, which can be attributed to the fact that the technology designers do not take into account the needs of older people [14].

Humans are generally considered to have finite information processing resources [15, 16], and situations that make multiple calls on these resources, particularly those that require divided attention, may tax capacity to the point that performance and safety margins suffer [17]. Under actual driving conditions, older drivers are known to self-regulate workload, e.g., drive slower, travel during less congested periods, and avoid distracting technologies [18, 19]. Indeed, there is still much to be learned about the efficacy of design aids and supporting tools for the older adults in particular. Knowledge on the best way to educate and train older adults to interact with new technologies is also lacking [14]. The "Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems" (2006), known as "Driver Focus – Telematics Guidelines", was developed to provide design criteria and evaluation procedures aimed at minimizing driver distraction potential to the Alliance of Automobile Manufacturers members for creating visual-manual interaction telematic systems, while the vehicle is in motion. Not surprisingly, test subjects were licensed drivers between the ages of 45 years old and 65 years old. Thus, the design of the system shall be such that the interaction shall not demand the dedication of both hands simultaneously, allowing for one hand to be on the steering wheel.

A study by Bekiaris, Panou and Touliou (2013) also addresses the needs of older and other mobility-restricted divers, concluding that there are three major key points that need to be addressed in the design of ADAS: the adequacy of ADAS warning algorithms, the restriction of accessory information services while the vehicle is in motion, and the synchronization of the articulation of ADAS with the supply of other infotainment services.

For that reason, this paper aims to present key workload indicators that can be used by the car autonomous driving systems to establish the more efficient means to keep the senior drivers informed about the driving task and surrounding environment, allowing them to benefit from other entertainment applications and safely resume the driving task.

2 State of the Art

According to Merat and Lee (2012) Advanced Driver Assistance Systems (ADAS) are projected to help users during the driving task. Many different parameters are being constantly verified and whenever thresholds are surpassed, the system informs the driver. ADAS systems, mainly present visual, auditory and haptic warnings [20], nevertheless these systems, which are designed to help, if badly designed, may distract the driver and even increase workload, enhancing the possibility of driving distraction and for that making driving less safe [21]. SAE International (2016) suggests a broader understanding of driving and for that purpose presents the concept of Dynamic Driving Task (DDT) as all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints, and including without limitation: Lateral vehicle motion control via steering (operational); Longitudinal vehicle motion control via acceleration and deceleration (operational); Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical); Object and event response execution (operational and tactical); Maneuver planning (tactical); and Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical). Taking level 3, as an example, while the ADAS is engaged, the user must be receptive to a request to intervene and respond by performing DDT fallback in a timely manner [5].

Studies show that an increase of the workload to the driver will cause him to focus on the driving itself, relegating to a less demanding occasion the appreciation of his surroundings environment, thereby decreasing the horizontal gaze movement, which renders eye movement behavior an important indicator of the driver workload, already referred in several literature [22–25]. Nevertheless, studies show that people suffering from HL may compensate their shortcomings in detecting auditory events away from their central field of view by increasing their attention to their peripheral field of view. It is not possible to assess, yet, whether this phenomenon is also mirrored in the driving scenario. Thorslund, Ahlström, Peters, Eriksson, Lidestam and Lyxell (2014) postulated that, between older drivers with and without HL, more active visual scanning, with more frequent glances of shorter duration were expected from the first group. Their findings indicate that visual behaviors are bound to the driving condition, wherein while driving and performing a secondary task, both groups of drivers equally look away from the road, with the HL group showing more frequent glances of shorter duration. When driving and performing a secondary task, though, the HL group performed worse, presenting fewer and more focused glances, assessing the surrounding traffic environment prior to engaging on the secondary task. These results may suggest a dynamic relationship between workload and horizontal gaze, in which HL may have a mediating effect.

The performance indicators used to assess eye movement behavior include: number of glances away from the road; mean duration of glances away from the road; maximum duration of glances away from the road; and percentage of time focusing the road. [11]. According to Hart (2006) the workload experimented by an individual can be defined as the cost of accomplishment of certain mission requirements for the user, or, the portion of human resources an operator expends when performing a specific task [26].

As posed by the authors: "Mental workload is a peculiar concept that has intuitive appeal" remaining difficult to define. Many definitions have been made but it is clear that a consensual definition does not exist [27]. Processing human information, in general, is considered as limited [28, 29]. Nevertheless, mental workload designates the amount of resources committed for the processing of a certain task [30], it is connected to the task characteristics, the situation and the person.

As it is very important to measure mental workload, in order to understand the problematic regarding the interaction between drivers and cars, it is important that the measurement methods are valid [28]. O'Donnell and Eggemeier (1986) indicate that there are three main approaches for the measurement of mental workload: Subjective measures; Performance-based measures; Physiological measures.

The main advantage that is indicated for the use of physiological methods is that these allow a direct and continuous measurement of the mental workload level [28]. According to Heine et al. (2017), Paxion et al. (2014) and Miller (2001) the most used physiological method for estimating mental workload is the electrocardiogram (ECG). Despite the major social and economic benefits that ADAS technology enables, it is not without risk.

First, the ADAS may encourage a driver to continue driving in situations he could have stopped otherwise, as is the case of collision avoidance systems in fog [31]. At the same time, ADAS can fail from either random (e.g., communications interference and unexpected component failures) or systematic faults (for instance, software failures or overall failures in the design of the system). Adding that to the fact that the very own systems designed to alleviate driving strain might, themselves, increase stress by demanding the driver to execute other tasks (aggravated by the lack of user knowledge), the inefficacy in the use of such systems can, in fact, constitute a danger itself [32].

Although intending on minimizing the effects of in-vehicle systems overload on the driver, input sensory stimuli and sources of additional mental workload inevitably emerge during normal driving and may be compounded by the ADAS. This adding workload brought by the ADAS should not exceed the driver's visual, auditory, and haptic and cognitive capacities, but often arise from complex designs with poorly designed feedback mechanisms, which end up diminish the safety value of ADAS and the acceptability of the system [33].

As if it were not enough, evidence shows that excessive reliance on automated can damage the driving task performance. Claims are that autonomous performance will only relegate abnormal tasks to manual handling, which means that manual driving will be dealing with only sporadic situations for which the drivers will be highly estranged with, potentially showing reactions that will fall short of optimal [32]. Furthermore, for the majority of the time, drivers will be performing a monitoring task rather than a driving task, which has proven to induce high levels of workload. This shift of the attention gives origin to complacency, which negatively influences alertness and reaction time [32].

According to the 1968 Vienna Convention on Road Traffic: "Every driver of a vehicle shall in all circumstances have his vehicle under control so as to be able to exercise due and proper care and to be at all times in a position to perform all maneuvers required of him.". Several industry experts have explored this topic, converging to the notion that ADAS comply with this convention so long the responsibility is not completely shifted to the system and the driver is able to shut down or override the driving maneuver [32]. This is very important because it imputes responsibility for the driving task, even at high levels of autonomy, to the driver. All the components of the vehicle which provide feedback to the driver are sources of mental and manual workload. Hence, all stimuli (visual, auditory, haptic and cognitive) contribute to the driver's workload [33].

The visual space capacity of the driver allows him to deviate his gaze from the road ahead for certain periods, which may configure a visual diversion or a distraction, being that the latter emerges when this capacity is superseded by a stimulus (prolonged fixation on an object). The auditory capacity of drivers with normal hearing exceeds their visual capacity (even though the first is the most difficult capacity to quantify), as they can receive more simultaneous distinct auditory inputs before achieving a level of (mental or cognitive) workload that may already pose a risk [33]. Cognitive overload may arise from something as simple as driving and wondering about things other than driving and the driver experiences manual overload when he engages in secondary manipulation tasks during driving such as adjusting vehicle controls [33]. Haptic feedbacks may allow control of the vehicle and can either provide warnings to the driver instead of, or augment audio/visual feedbacks when combined with the latter, not adding a cognitive workload in many circumstances [33]. Olfactory feedbacks are not currently being used as feedback mechanisms, but there are incipient studies on their triggering advantages on facilitating tactile performance and maintaining alertness [33]. In short, all external and internal stimuli that adds to the driving function affects the driver mental workload. The factors that compound for cognitive and mental workload are: traffic, poor visibility and lighting, bad weather, surface poor conditions, external noise, in-vehicle noise, poorly or partially functioning systems (e.g., windshield wiper), poorly responding vehicle dynamics (e.g., braking response), lost directions, sources of anxiety (e.g., urgency of trip) and the driver's health and mood [33].

Age has proven to play a role in perception-response time and in the response reaction of the older drivers. ADAS must ensure safe operation by older drivers.

According to the Transportation Research Circular 419, older drivers' sequential psychomotor response times are higher than young drivers' and they are at higher risk when a sequence of control movements are required (e.g., during an emergency evasive maneuver immediately following another movement) [34].

While age diversity has previously received limited consideration, age has recently gained considerable interest as a key characteristic that is associated with physical and cognitive functions, experience with new technology, and ability to learn, which can together contribute to possible age differences in how people interact with autonomous vehicles [35].

The concept of vigilance refers to the degree of attention the driver is allocating to the primary task of driving. It is generally accepted that if the driver is in normal and vigilant driving mode, he is looking towards the road ahead continuously with appropriate attention, and that any deviations from this posture manifest a degree of lack of vigilance. The driver's degree of vigilance can be related to the state of his eyes and mouth (whether open or closed) and to the blinking and yawning frequency. The causes of vigilance decrement include fatigue, drowsiness, and external disturbances. Fatigue and drowsiness are associated with a higher percentage of eye closure, measured by a variable PERCLOS, which expresses the percentage of time in which the eyes of the driver are between 80% and 100% closed. Fatigue may be manifested through fixating on objects, frequent blinking, head nodding and unnatural facial features. The measurement of vigilance or statement of appropriate levels of vigilance is a challenge, because it varies among drivers. Nevertheless, many development have been achieved through eye tracking and computer vision technology, that have enabled the measurement of some facial and eye features accurately and consequent correlation with vigilance. The Japanese National Institute of Advanced Industrial Science and Technology developed a driver monitoring system integrated with driver assistance, the "ITS View-Aid System," in which driver warnings and displays are optimized according to measures such as level of alertness, gaze direction, age, road condition and inter-vehicle distance [36].

3 Methodology

Literature review followed the PRISMA Statement methodology [37], by which the adopted inclusion criteria included only original studies written in English and published until January 2017. The search terms used were "workload", "driver", "age" and after the initial results the next step was to address only the topics related with "cars", "elderly" and "autonomous" for those were considered the most probable to have publications of relevance to the present study.

4 Results

Workload measures can be classified as physiological, subjective or performance, according to their nature. Physiological measures include cardiac measures (heart rate, heart rate variability and blood pressure), respiratory measures (respiratory rate, volume and concentration of carbon-dioxide in air flow), eye activity measures (eye blink rate and interval of closure, horizontal eye activity, pupil diameter, eye fixations), speech measures (pitch, rate, loudness) and brain activity (measured through electroencephalogram and electrooculogram). The horizontal eye movement (HEM) is considered a good indicator of visual and mental workload, as it scans the eyes' movements used to obtain information from the instrument panel (speedometer, side and rear-view mirrors). It is the measure that shows more promise in assessing visual and mental workload and research shows that an increase of HEM manifests an increase in the workload, as does the increase of the pupil diameter [38]. Eye fixations are associated with performance measures and are just considered as diagnostic measures. Fixation Fraction (FF) relates to eye fixation time [10].

Physiological measures based on other outputs of the body may have potential for measuring mental workload in driving situations, but because they are extremely intrusive and/or require expensive machinery or tests for measurement, would be hard to use in practical settings [38]. Other brain activity measures are the Electromyogram (EMG), which measures ‘task irrelevant’ facial muscles that are not required in the motor performance of a task, for different facial muscles have been found to differentially sense changes in mental workload (e.g., frontalis and the corrugator) and the ElectroCardio-Gram (ECG), which is related to cardiac measures, specifically heart rate variability (HRV) [38]. HRV may not be a good indicator of workload in the elderly, because this physiologic signal decreases with age [10]. Event related potentials (ERPs) are related to fluctuations in the EEG, which has an advantage of being good in the diagnostic of mental processing [38]. Electrodermal activity (EDA) measures electrical changes in the skin and has been shown to increase with the workload, even though it lacks specificity. Hormone levels also vary in situations of extreme stress and are usually used for long-term studies on workload [38]. Mehler, B. Reimer, B. and F. Coughlin, J. (2012) found heart rate and skin conductance levels (SCL) to be increased in an incremental and statistically significant fashion with each level of increased cognitive demand imposed by their study design [39].

The amount of information used in working memory is assessed through subjective measures. It is a simplistic approach, by which the statement of feeling a lot of workload deems the task as high in workload. Even though less precise, subjective measures are more practical. The subjective tests are flexible of account for the different capabilities of the individuals, but considered very valuable and have proven to correlate with physiological measures of workload such as heart rate variability. These measures have also been considered the easiest in assessing workload and proven an accurate, more direct indicator of workload than physiological measures. Other advantages include being the most flexible and convenient, and the least intrusive, time consuming and expensive for assessing workload. These measures are not disadvantage free, though, for instance, problems may occur with familiarity and the chosen rating scale [38].

Subjective measures can be divided into unidimensional and multidimensional ratings. Unidimensional rating scales are the simplest because they do not imply the use of complicated analysis techniques. Also, the scale has (obviously) only one dimension and is, usually, more sensitive than the multidimensional scale, which encompasses a more complex and more time consuming form of measurement, and has between three and six dimensions. Moreover, the multidimensional scale is generally more diagnostic [38]. Performance, or degree of effectiveness in accomplishing a given task, is resorted to for measuring workload through primary and secondary tasks. Evidently, humans are limited in their resources. Thus, if a task demands the same resource structure, performance will be penalized. Hence, the workload can be estimated by measuring the decrement in performance by the primary or the secondary tasks. Even though the primary task measure is more direct for measuring workload, both are used and leastwise moderately accepted [38].

Bruni, Chang, Carlin, Swanson and Pratt [40] classify differently the measures as so: physiologic measures (which include pupillary response, blink rate, heart rate, or galvanic skin response), system-based measures (e.g., number and complexity of pilot tasks, number of tasks that compete for time or resources), and subjective measures (such as, for each pilot task, mental demand, physical demand, temporal demand, performance, difficulty, or frustration) [40].

A summary of the workload measures and correlation with workload is presented in Table 1.

Table 1. Summary of workload measures.

Measure			Result of increased workload
Physiological	Cardiac	Heart rate	Increases
		Heart rate variability	Decreases
		Blood pressure	Increases
	Respiratory	Respiratory rate	Increases
		Volume per breath	Decreases
	Brain activity	Electroencephalogram	Alpha waves replaced by Beta waves
		Electrooculogram	Less jumps in data (Related to gaze and blink rate)
		Eye blink measures	Rate decreases; pupil diameter increases
		Speech measures	Pitch, loudness and rate increase
	Integumentary	Electrodermal activity/ skin conductance levels	Increases
Subjective	Unidimensional	Modified Cooper-Harper scale	Higher rating
		Overall workload scale	Higher rating
	Multidimensional	NASA task load index scale	Higher rating
		Subjective workload assessment technique	Higher rating
Performance	Primary		Decreases
	Secondary		Decreases

According to Son, Lee and Kim (2011) the increase of the use of in-vehicle technologies can increase driver distraction, and a significant proportion of the distraction may arise not from its manual manipulation but from cognitive consequences in their use. Indeed, the authors state that older drivers are less capable when engaging in secondary tasks. In fact, older adults' lower levels of energetic arousal cause them to suffer vigilance loss, an aspect of monitoring found in highly reliable automated systems, making them more vulnerable than younger adults to automation-related reductions in monitoring efficiency [42]. This results in older adults taking more conservative time gap decisions [43]. Even though older drivers present decremented attentional capacity, their experience and age usually compensate, being the exception situations with high momentary mental workload, in which they fail with severe consequences. The majority of older drivers' accidents are caused by inattentive driving (e.g., failing to look forward, judgmental error and delayed discovery) [41]. Thus, compensatory behaviors like speed adjustment for coping with increasing workload may be feasible indicators of workload in seniors. Risky decisions arise for older drivers when time pressure is added, because compensatory strategies become ineffective [43]. De Waard (1996) states that speed measures are the most reliable, sensitive indicators of increased mental load in both laboratory and simulator experiments.

The findings of this research are that the ability of maintaining longitudinal control can deteriorate with increased cognitive workload, and therefore, this may constitute another important indicator of workload in seniors [41]. Even with compensatory driving strategies, like lower speed, driving is an activity that leads to a considerable higher mental workload for the older drivers than for the younger. This aftermath was aggravated in more complex driving situations, e.g., overtaking [44].

5 Conclusion

Driving is an activity that leads to a considerable higher mental workload for the older drivers when comparing to the younger drivers. Compensatory driving strategies, like speed adjusting are mechanisms that older people adopt to cope with this high-demanding task, and even more so in more complex driving situations, such as roundabouts, intersections and overtaking. The main indicators of the seniors´ workload while driving are the adjustment of speed, lateral and longitudinal maintenance control. The measurement of workload through signals which suffer decay with aging, like HRV, should take into account that these are can be poor indicators of workload in older drivers. Literature review enhances the influence of compensatory behaviors like adjustment of speed and grants them the most feasible factors for determining elderly workload during the task of driving.

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A Study of the Knowledge, Attitude, Behaviour and Practices Pertaining to the Safety of Public School Children Among School Van Drivers in the 5 Towns of the Republic of Mauritius

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Abstract. Travelling to any educational institutions in the Republic of Mauritius is a free service provided by the government, but because of hectic lifestyles of parents and heavy traffic congestions, many parents avail of the services of school vans. However, the image of such vans has been tarnished due to some serious incidents while commuting the children to and from school. This study uses the KABP constructs to assess school van driver's perceptions in ensuring children health and safety when commuting to and from school. Questionnaires were distributed to sixty-eight school van drivers. Findings indicated that drivers have sound Knowledge, positive Attitude, good Practices and proper intentional Behaviours in order to ensure the health and safety of the children commuting in their school vans. The study has helped in identifying the relevant relationships between Knowledge, Attitude, Behaviour and Practices of school van drivers in Mauritius.

Keywords: Drivers · Children · School vans · KABP

1 Introduction

The World Health Organisation made Road Safety the theme of World Health Day in April 2004. Road accidents are the principle cause of death of young man under 25 [1, 17]. According to Peden et al. [13], accidents are also among one of the leading causes of death and injury for children worldwide. Although the way children travel and their travel experiences have been researched from different perspectives [9, 12], the safety perspective as far as transportation of children is concerned has been very modest till now.

However, engagement in these behavioural processes is not a 'quick fix', and there is a need to investigate beforehand its fundamental constituting elements [7]. The health and safety field investigates children's harm prevention and health promotion [3] and among the various areas of interest is the prevention of injuries, the embracing of healthy habits, proper practice development, as well as policy making [3]. These areas of interest are mainly present when considering major health and safety risks in child travel, and more specifically in school bus/vans [14].

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This study takes place in the Republic of Mauritius where, since September 2005, travelling to school as well as to any tertiary institutions by public transport is a free service provided to all students by the Government. Approximately 50,000 children are using school vans to commute to and from school (Le DefiQuotidien, 28th May 2012). However, over the past few years, because of some recurring events, the reputation of these private contract buses has been tarnished. They are seen as a lucrative business, having low concern about the responsibilities regarding the safety and health of children commuting with them. There are evidences of not only many school buses operating illegally (Le DefiQuotidien, 28th June 2012 and 01st June 2012), but also school van operators have been blamed to be the cause of few fatal accidents involving children (Le DefiQuotidien, 21st March 2012 and 25th April 2012). Even after more than 10 years that laws and regulations have been introduced to ensure the safety of child passengers travelling by the private school buses, the situation has not really changed in Mauritius.

The researchers therefore try to elucidate key aspects pertaining to the safety of children while commuting to and from school, using the Knowledge, Attitude, Behaviour and Practices (KABP) Approach among school van drivers and they attempt to:

(i) explore the understanding of school van drivers' knowledge, attitude and behaviour in the course of their duties
(ii) examine the health and safety KABP of school van drivers when commuting young children to and from school

2 Literature Review

2.1 Health and Safety Among Commuting Children

There has been an increasing link between transport and health of individuals over the few recent years [16]. Closely linked to road transport and safety, but yet not adequately researched is the reality which school children face as far as their transportation and road accidents are concerned. Health and Safety is influenced by various factors; including the authorities' attitudes to promote it and act upon it, to the different stakeholders' attitude and commitment towards a healthy and safe environment [7]. Improvement in health and safety performances is done through the introduction of behavioural health and safety processes, which identifies and reduces unsafe and unhealthy practices [7]. However, these processes are not a 'quick fix' and there is a need not to overlook its fundamental constituting elements [7]. Therefore, in order for these processes to be efficient, one should start by concentrating on the underlying laws and regulations present, the nature and characteristics of the area or setting in which they would be applied (e.g. industries, transportation, hospitals, etc.), as well as the roles played in by the different stakeholders [7].

Behaviour is defined as any observable action by an individual [7]. It has been estimated by the Health and Safety Executive in UK [6] that up to 80% of accidents was due to people's behaviour, both in the form of acts and omissions. These thus add up to pre-existing threatening factors, to end up as a negative event [6]. Various reasons have been identified as leading to 'at risk' behaviours (see for example [7]). Adopting therefore a behaviour-based perspective enables to focus on these observable and measurable unsafe and unhealthy behaviours in a particular setting [7]. It also allows treating safe and healthy behaviours as critical skills that need to be adopted through a change in the setting's culture [7]. Moreover, from this behaviour-based perspective, adult individuals are recognised and considered "as a mature human being with a genuine interest in their own wellbeing, who contribute best when they can see that they themselves can influence their own safety" ([7], p. 3).

Operating a school bus/van has now become very challenging, due to the new safety measures and the governing legislations being continually developed, assessed and modified [5]. Furthermore, with the several accidents involving school vans, the safety issue has been questioned and promoted to a higher level [11]. The Health and Safety field care for children in preventing harm and promoting health [3]. As opposed to adults, school children have specific safety travel requirements, which are in relation to the major health risk to child travel in vehicles. These include trauma and accidental injury [14]. Much can be done by the concerned stakeholders to prevent these school bus related trauma and injuries from happening [10]. School bus operators, parents, policy makers as well as the school administration have roles and responsibilities in this public health and safety issue [10]. Moreover different child's (i.e. age, sex and anthropometry), vehicle's (i.e. seating

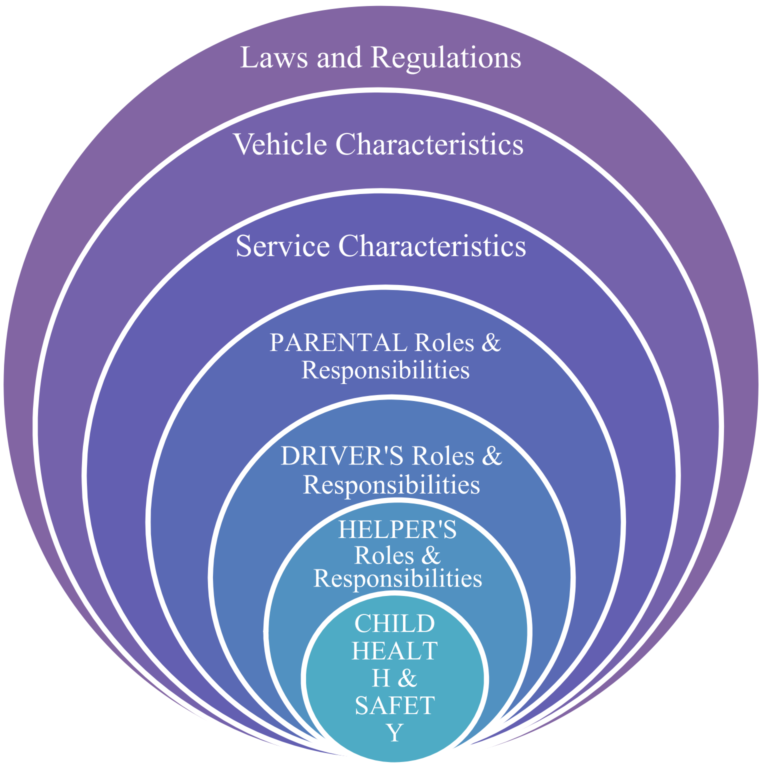

Fig. 1. Determinants of child health and safety using school bus. Source: adapted from [2]

capacity, recognition marks, features like seat belts, space of movement and mobility, and seating ergonomics) and service's (i.e. hours- morning and evening, journey time, and days of the week) characteristics need also to be considered [2]. This issue therefore is approached on multiple levels, as shown in Fig. 1, as they all have a role and shared responsibilities in the provision health and safety to children [2, 10].

However, since defined roles and responsibilities are still unstructured in the Mauritian context, their investigation needs to be supported by a strong scientific approach and underlying relevant theory assessing the behaviours. Thus, the KAPB and the TPB have shown to be relevant approaches to investigate road safety and health behaviours.

2.2 Knowledge, Attitude, Behaviour and Practices (KABP) Approach

The KABP approach, which has as main purpose the study of Knowledge, Attitude, Behaviour and Practices, is considered as an educational investigation of the community. It has been used to analyse the response of patients towards treatment [8], the knowledge of breastfeeding among mothers (UNFAO & FSAU Report [18], the behaviour of nurses with respect to care giving [19], and among practicing dentists [4]. Using this approach in the school van context will help in elucidating what stakeholders know about child health and safety in commuting to and from school, how they feel about it, how they behave and, eventually which coping practices have been adopted. The 'Knowledge' would more specifically gauge what the stakeholders know about their role and responsibilities in ensuring safety when commuting children as well as general road safety. 'Attitude' would reflect the stakeholders' feelings about health and safety of school children while commuting them. 'Behaviour' and 'Practices' would involve how they would translate their knowledge and attitude through actions while at work.

3 Method

The survey method was adopted for the purpose of this study. The target group were drivers of school vans. Convenient sampling was used to select the van drivers from the five towns of the Island. The participants were recruited through the local private school bus association "Association of School Bus Owners", the National Transport Authority (NTA) and by peer reference. In all, 68 drivers agreed to take part in the study.

The questionnaire for each group was based on the literature pertaining to KABP constructs, and the salient themes in the field of health and safety (i.e. Health, Ergonomics, Physical Hazards, Hygiene, Safety, and Prevention). It contained five sections as follows: Section A consisted of demographic information about participants' gender, age, professional driving experience, work experience, education level, no. of road accidents, no. of trips per day, no. of children carried, registration with authorities, helper's presence and working area. Section B consisted of an adapted version of the Driver Attitude Questionnaire (DAQ)-SF assessing the drivers' attitude towards safe driving, based on three sub-sections: the Law, the other drivers and me-the driver respectively [15]. The 12 items were measured using a 5-point Likert scale (1 = Strongly Disagree – 5 = Strongly Agree). Section C consisted of 9 questions assessing

Knowledge. This factor measured driver's knowledge about child safety (e.g. as a driver, I think I should get registered with the NTA as School Bus). Section D consisted of the Drivers' practices and had 24 items. The drivers' practices consisted of 5 sub-sections, namely Health, Ergonomics, Physical Hazards, Hygiene and Others.

Finally, Section E consisted of 18 questions assessing the drivers' intention in ensuring child safety (e.g. as a driver, I intend to ensure that there is a helper in the van). The scale uses a 5-point scale from 5 (definitely do) to 1 (definitely do not). The drivers' intentions were grouped into 3 sub-sections, which are namely Hazards, Safety and Prevention. A pilot test was carried out with 4 drivers involved in the provision of the service in doing so, any ambiguities were addressed. Since most of the participants were not conversant with the English language, they were assisted by the researchers in filling-up their surveys.

Ethical research practice was also ensured in asking for informed consent before filling in the survey, although the questionnaire was an anonymous one. Despite all these steps taken, resistance among the drivers were noted, mainly because they thought that the survey was a means to get inside information regarding their business. Another major problem encountered was the restrained time schedule of the drivers.

4 Findings

4.1 Knowledge

The least important item in the knowledge variable was found to be the presence of a helper to attend the children during the journey, at pick up and at drop off (Mean 4.65), as compared to the most important one as being the respect of road signs (Mean 4.85). Ensuring the safe drop off and pick up of the young travellers also yield a considerable high score (Mean 4.84).

4.2 Attitude

The Attitude variable was broken into three themes, Law, Other School Van drivers and self. Figures show that in general, attitude towards overtaking is of least importance in ensuring the safety of children in the school van (Mean 2.22). Attitude towards close following was of most importance when considering the law, as opposed to the two other themes (i.e. others and Self), in which drink driving is of utmost importance (Mean 1.21).

4.3 Practices

The Practices variable was broken into five themes – Health, Ergonomics, Physical Hazards, Hygiene and Others. Figures obtained show that the most salient theme is driver's concern more about Hygiene practices (Mean 4.68). When considering the Health theme, the most salient item emerged as catering for those who are travel sick (Mean 4.41), and the least salient one, the separation of those having flu/cold to avoid contamination (Mean 3.30). For the Ergonomics theme, much importance was given to the provision of good aeration in the van (Mean 4.66), than for the proper disposition of the children luggage (Mean 4.66). Ensuring the van's fitness (Mean 4.74) was the most salient item when considering Physical Hazards, than ensuring that all the children are sitting at the back with the helper (Mean 4.32). When considering the Hygiene theme, the most important theme emerged as the helper's and driver's grooming (Mean 4.86), and the least one, the maintenance of the air conditioner for an allergy free environment (Mean 4.38). When considering the "Other Stakeholders" theme, figures indicate that the drivers' acknowledge that the parents totally rely on their service as least important item (Mean 4.51), and the most important one was the communication with those same parents (Mean 5.22).

4.4 Practices

The Intention variable is broken into three themes – Hazardous Behaviour, Safety and Prevention. There is a significant difference among the mean scores of these three themes, with the most salient ones being the Drivers' intention to further adopt Hazardous and Safety behaviours (Mean 4.71). When considering the Hazardous theme, the most salient items happened to be permanent fitness of the van (Mean 4.88) and the maintenance of the van (Mean 4.88), and the least salient one, having a seat belt for each passenger (Mean 4.35). It has been found that for the Safety theme, much importance is given to the real job commitment as children lives are involved (Mean 4.82), than for the avoidance of phone while driving (Mean 4.54). Providing one's views to authorities to ameliorate comfort and safety (Mean 4.69) is the most salient item when considering Prevention, than getting overloaded with work, which is seen as least important (Mean 4.59).

In line with the objectives of the study, the overall means for all the variables under the KABP construct were identified. The overall mean for Attitude was 4.30 (SD = .772), while that for Knowledge was 4.76 (SD = .471). The overall mean Practices was 4.51 (SD = .654), and that for Intention was 4.69 (SD = .533) (see Table 1). A significant difference among the mean scores of the different construct of the KABP is noted, with the most salient one being the drivers' Knowledge in ensuring the health and safety of the children ($p < .001$).

Table 1. Drivers descriptive results for attitude, knowledge, practices and intentions.

KABP	Mean	Std. deviation	t-value	Sig.
Knowledge	4.76	.4714	30.844	.000
Attitude	4.30	.772	13.875	.000
Practices	4.51	.654	18.585	.000
Behavioural intentions	4.69	.533	25.728	.000

5 Discussion

5.1 Drivers' Knowledge

The findings as above indicate that drivers have good and sound knowledge of what they should be doing to ensure the health and safety of the children commuting with them. However a lack in recognising the importance of some salient components in their operation has also been noted. It has been identified that the majority of the drivers gave very much importance to 'respecting the road signs' in commuting school children to ensure their health and safety, while neglecting the importance of the helper's role in ensuring the health and safety of the children on the journey. This discrepancy can be explained by the fact that 'respecting road signs', being a fundamental traffic law, has become part of the routine of these drivers. On the other hand, the new law regarding the compulsory presence of a helper is not taken seriously by some drivers who do not understand the need for it as they believe that "they themselves, can do the work". Therefore, there is a need to reinforce and consolidate the knowledge of the drivers, through proper training, as it is the case in the foreign countries (See for example Florida Transit Handbook, 2012; Pennsylvania School Bus Driver's Manual, n.d.; School Bus Drivers Handbook, n.d.).

5.2 Drivers' Attitude

A discrepancy has been noted among the drivers' attitude towards the law, the other drivers and themselves, in ensuring the health and safety of the children commuting with them. It has been noted that drivers have a strong positive attitude towards abiding to the country's law to ensure the health and safety of the children as, if being sanctioned by the concerned authorities they will automatically be sent to court which might impact on their driving permit. The drivers are more concerned about "close following" being dangerous for the health and safety of the children than overtaking, as according to them when following close, one does not have much control due to the vehicle in front, while overtaking is in the drivers' full control. The drivers perceive drinking & driving as dangerous for the health and safety of the children. However, as for the law, they give low importance to the danger that overtaking might bring for the above mentioned reason. Also the other drivers are perceived as having good health and safety behaviours, even if the drivers are having a weak positive attitude towards them. It has been noted that, as for them drink and driving from other drivers are also perceived as dangerous for the health and safety of the children, while for other drivers also, overtaking is not an issue.

5.3 Drivers' Practices

It has been noted that the drivers are very concerned with hygiene practices. The most important for them is being well groomed and clean when working with the children, and least concerned with the air conditioner filter being well maintained and allergy free, as these are usually not in use. The second most important issue identified, is the "Other

Stakeholders", which would include the help received from parents and school, as well as preventive measures in ensuring the health and safety of the children commuting with them. The drivers identified that for their practice to be in favour of the children's health and safety, communication with parents is the key, while appraising that they are the sole reliance of parents in taking their children to and from school is of low importance. The third important practice is catering for physical hazards. The drivers are concerned about ensuring their van's fitness as an important practice of the health and safety of the children, as if the van is not fit for road, they will not have the right to run it. However, ensuring that all the children are sitting back with the helper is of least importance, as in some vans, small children are sitting in front or there might be no helper at all in the van. Moreover, it has also been noted that practices concerning ergonomics and health, are of lower importance respectively, as most of the concerned practices are more, according to the drivers, the helpers' roles and duties, and this is a recurrent finding through the research. This can, as mentioned before be supported by drivers and helpers, having established their roles and duties, work in a team to ensure the health and safety of the children.

5.4 Drivers' Intention

It has been noted that drivers were more concerned in changing and improving the risks and hazards than improving behaviours, to ensure the health and safety of the children commuting with them. It has also been found that they intend to be more committed to their job, as life of children is involved. However, not using the phone while driving has been given low importance, as according to them, parents can be calling them anytime. Moreover, when considering hazards eliminating behaviours, it has been found that the drivers intend to always keep their vehicle fit for the transportation of children and thus the school van is well maintained.

Furthermore, issues like children school bags being stored in a dedicated place, is considered of least importance in ensuring the health and safety of the children. This can be explained by the fact the school van is either overcrowded or the drivers have a hectic schedule and thus might not have enough time to wait for the child to search for his bag at the time of drop out. These findings therefore show that while the drivers have good intentions tend to ensure best transport, comfort and safety to the children, they do not intend to overload themselves with work. They might be more concerned about a good yield in the end, i.e. getting the van overloaded with children or maximising the number of trips.

6 Recommendations

6.1 Focused, Specialised Training and Examinations to Reinforcing the Operators' "Knowledge" and Eventually "Practice"

The findings clearly revealed a strong positive relationship between Knowledge and Practices among operators surveyed. Thus, the more and/or better Knowledge will the drivers have, the safer will be their Practices adopted. Having said so, better and more appropriate training could be provided to drivers which would result in the adoption of safer practices on their part. Concerned authorities should thus provide for more focused and school van operator oriented training. For example, drivers could be provided specialised training pertaining to safe driving, road safety and health and safety of commuting children.

This study has proved that formalised and specialised training is of utmost important to drivers. Parallel with the above, authorities concerned might even also go further and provide for adequate testing of Knowledge through specialised examinations for school van operators (i.e. practical and oral) before issuing of licences and/or registrations. Currently, in Mauritius, this is the case only for taxi drivers, but, this study has provided enough evidence for such a practice to be extended to school van operators as well.

6.2 Reinforcement of Laws for Improved "Attitude"

This study revealed the positive "Attitude" that school van drivers have towards the job they are doing. They acknowledge that considerable number of parents rely on them for the services they offer, but most importantly for ensuring that their children have a safe and healthy journey to and from school.

The findings show that the drivers paid much importance to their road safety behaviours (close following, drinking, and overtaking) and van maintenance more precisely because of exigencies of the law. In this respect, concerned authorities should tighten supervision and strengthen, if required, existing laws governing the operation of school vans (e.g. registrations and abiding to road traffic laws). Such practices will further consolidate the good "Attitude" of drivers towards their jobs.

6.3 Provision of Improved Infrastructure to Encourage Good "Intention"

As indicated in the study, although the intention to provide for appropriate infrastructure is here, there are, for example no rules regarding the wearing of safety belts among commuting children. More so, many schools still do not possess a dedicated lay by for the pickup and drop off of school children. The traffic authorities could thus, in a first instance, ensure that in front of each school there is a safe drop off and pick up area, in addition to the pedestrian and traffic officer already present. In doing so, school van drivers can safely drop off and pick up the children.

7 Conclusion and Scope for Further Research

This study has provided some rich insight about the perception of health and safety of commuting children among Mauritian school van drivers through KABP constructs. The study does have some limitations, in the sense that it mainly described the drivers' perception (i.e. through the descriptive analyses made) and only investigated the relationship between the KABP constructs. Therefore, no causality can be inferred through these findings. This therefore paves the way for further research. More so, literature being scarce in using KABP constructs on the health and safety of children commuting to and from school, this study sets the way for future research in this direction. Further research could investigate into the causality of these constructs on health and safety, while others could investigate into the other stakeholders' perception (i.e. the parents, the school, traffic police officers). This would enable triangulation of the findings and therefore portray a fairer picture of the issue under study.

Nevertheless, this piece of work provides insightful recommendations for not only researchers in the field, but has also provided adequate scientific data for policy makers The need of having more studies in this field is undeniable and thus encouraged, because of the importance it holds in the everyday life of parents and children attending school.

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An Integrative Literature Review: What Are the Barriers that Stop Organisations from Learning the Lessons Highlighted in Serious Incident Investigations?

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Abstract. It has been suggested that we have moved into an adaptive age of safety and that one of the key accident prevention strategies in this age is that of 'organisational learning'. Effective safety management in this age requires organisations to investigate and learn from (major/serious) incidents. This paper aims to outline some of the most significant barriers to organisational learning following major events, through an integrative review, by reviewing the current literature around incident reporting. This review identified five key themes in the published literature, and a gap between knowledge and actual practice in industry. As a community of safety professionals there is much we can do to close this gap, through empirical studies aimed to further understanding and break down some of these learning barriers.

Keywords: Incident investigation · Accident investigation · Organisational learning · Integrative review

1 Introduction

It has been suggested that we have moved into an adaptive age of safety [2] where the focus is on building resilience [12]. This fifth age of safety follows technological, human error, socio-technical and cultural ages [2, 13] and builds on our understanding of how accidents are caused and how they can be prevented. The adaptive age recognizes that human adaptability plays an important role in the function of modern systems, and 'organisational learning' is one of main approaches for developing resilience [13]. These five ages of safety have been further condensed into three eras of safety, with the first era being contemporary approaches to safety, the second era being advanced approaches and the third and current era being sophisticated approaches [12]. In this era an organisation's ability to learn from the lessons of the past is crucial for improving and managing safety [12].

This paper looks at one aspect of organisational learning, namely investigation and reporting of events, and considers how organisations learn through this process. It includes a review of the published literature on the investigation and reporting of accidents and incidents in order to understand known or potential barriers to successful

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organisational learning following serious events, with the aim of determining best practice in this area of practice.

2 Methods for Search, Selection and Review

Although a number of methods are available for conducting reviews of published literature, including systematic and narrative reviews [3], an integrative review was chosen as the approach for this study. This method was selected in order to provide a deep understanding of key themes summarised from both theoretical and empirical data. This approach has been used in a number of safety related topics such as safety culture [18] and more recently in construction health and safety [14].

The ScienceDirect academic journal database was searched using keywords (Table 1) to identify related literature and the search results were screened for relevance to the research topic. The first screening was by journal title, the second through a review of the abstract and conclusions, and the third by review of the entire article. In addition, several articles identified from reference lists were also screened for inclusion (Fig. 1).

Table 1. Keywords used for literature search in Science Direct database [all sources (Social Sciences)]

Search	Keyword search	No. of articles retrieved	Abstract and conclusion reviewed	Article fully reviewed	Included in study
1	Incident investigation AND organisational learning	11	2	1	1
2	Accident investigation AND organisational learning	15	6	1	0
3	Incident investigation AND learning	69	15	8	7
4	Accident investigation AND learning	205	45	9	1

2.1 Inclusion and Exclusion of Articles

In order to include relevant articles a set of inclusion and exclusion criteria was applied (Table 2).

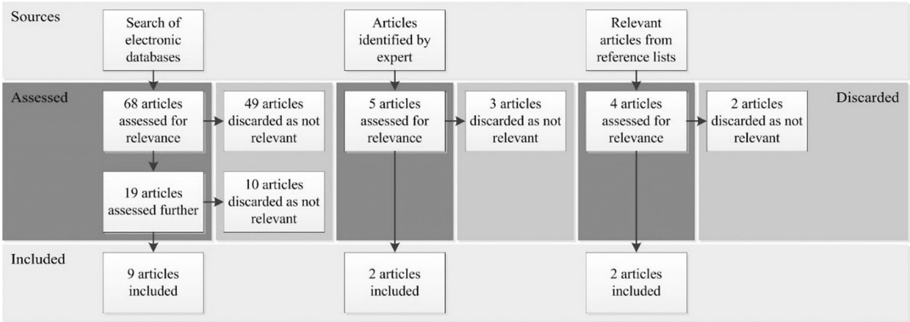

Fig. 1. Flow chart of literature search

Table 2. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Published between 2005 and 2015	Published prior to 2005
Published in English	Published in another language
Peer reviewed research article	Not peer reviewed article
Related to incident investigation	Did not relate to incident investigation
Related to "learning" from previous incidents	Not related to learning from previous incidents
Related to investigation methods and/or practice	Not related to investigation methods and/or practice

2.2 Critical Appraisal

The articles selected were critically appraised using a set of questions adapted from CASP [4] (Table 3) and screening results recorded (Table 4).

Table 3. Critical article appraisal questions

Screening questions
1. Aim/s: Was the aim of the research clear?
2. Method: Was the research methodology used appropriate?
3. Design: Did the study design address the aims of the research?
4. Data: Did the data collected address the research aim?
5. Data analysis: Was the data analysis sufficiently rigorous?
6. Bias: Was any bias considered adequately?
7. Findings: Are findings clearly stated?
8. Gap/s: Have gaps in the literature been clearly identified?
9. Acceptance: Can I accept the findings as true?
10. Value: Can I apply these findings to my own work?

*Adapted from CASP screening questions for qualitative research [Critical Appraisal Skills Programme (CASP) 4]

A thematic analysis of the articles was conducted by identifying themes and sub-themes found in the key findings of each article and these identified themes form the basis of the results of this report. Each theme goes part way to understanding the current barriers to organisational learning following incident investigation of serious events.

Table 4. Summary of critical appraisal of articles

Article	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Why do organisations not learn from incidents? Bottlenecks, causes and conditions for a failure to effectively learn [6]	✓	✓	✓	Limited	✓	✓	✓	✓	✓	✓
Learning from incidents: Practices at a Scandinavian factory [17]	✓	✓	✓	Limited	✓	✓	✓	✓	✓	✓
Assessing propensity to learn from safety related events [7]	✓	✓	✓	Limited	✓	✓	✓	✓	✓	✓
A framework for learning from incidents in the workplace [11]	✓	✓	✓	Limited	✓	✓	✓	✓	✓	✓
The context and habits of accident investigation practices: A study of 108 Swedish investigators [15]	✓	✓	✓	Limited	✓	✓	✓	✓	✓	✓
Learning from accidents – what more do we need to know? [10]	✓	✓	✓	Limited	✓	✓	✓	✓	✓	✓
Applying systems thinking to analyze and learn from events [9]	✓	✓	✓	Limited	✓	✓	✓	No	✓	Limited
Learning from adverse events in the nuclear power industry: Organisational learning, policy making and normalization [16]	✓	✓	✓	Limited	Limited	✓	✓	✓	✓	✓
Towards an evaluation of accident investigation methods in terms of their alignment with accident causation models [8]	✓	✓	✓	Limited	✓	✓	✓	No	✓	Limited
What is learning? A review of the Safety literature to define learning from incidents, accidents and disasters [5]	✓	✓	✓	Limited	✓	✓	✓	✓	✓	✓
Efficient and effective learning for safety from incidents [1]	✓	✓	✓	Limited	✓	✓	✓	✓	✓	✓

3 Findings and Discussion

Five key themes emerged as barriers to effective organisational learning from incidents.

3.1 Theme 1: Incident Reporting

Under-reporting of near misses [10], abnormal conditions or weak signals [7] can hide conditions that lead to major events. In industries where reporting levels are high this can cause important reports to be missed in the masses and go unnoticed [10]. Lack of trust or openness [10, 16], blame cultures [10, 11, 15] or lack of feedback [1, 5, 11] are all causes of non- reporting or underplaying events and can result in important information being withheld meaning opportunities to prevent incident occurrence or reoccurrence.

3.2 Theme 2: Incident Investigation

Time constraints [15], production pressures and the need to move on to other problems can hamper effective investigations [6] and a tendency to focus on technical symptoms and quick fixes [10, 17] often leaves structural or system issues unaddressed [6]. The possibility of disciplinary action can limit openness and transparency in investigations [11] and political pressures may result in incidents being normalised [5, 16] particularly in high risk industries.

3.3 Theme 3: Investigation Models and Methods

Many accident investigation methods require a high level of expertise [8, 17] and can lead to reliance on model-based software packages rather than the investigative processes behind them [17]. Some techniques can only find causes based on what the investigator currently knows and consider only events underlying an accident rather than the entire accident process [9]. Lindberg et al. [10] observed that there is little in the way of guidance material around the selection or practical use of methods.

3.4 Theme 4: Recommendations and Preventative Action Planning

Drupsteen and Hasle [6] found that planning actions formed the greatest bottleneck to learning from incidents. Actions may instead be skewed towards “what we can do something about” [17] rather than the deeper systemic issues. Some of the barriers to effective action planning include limited time to design and complete actions, budget [17], limited involvement of frontline staff and production focus [6, 9]. Actions are often determined by a small group [15, 17] yet to be successful event analysis must empower all stakeholders to question organisational and system issues without negative pressure [11].

3.5 Theme 5: Learning Opportunities

Review of action effectiveness or even action completion is often not done [5, 17] and it can be hard to reflect backwards with new events happening that require attention. Without senior leader support [6] it may be very difficult to achieve any lasting change that can prevent future events. Double-loop learning can address all contributing causes and conditions [1, 5, 6, 11] but normalization can prevent incidents becoming 'focusing events' where no double-loop learning occurs [5, 16].

Learning from events involves far more than simply disseminating information [10, 11]. Effective learning requires knowing how to learn [11, 15] and individual and active participation [5, 10] throughout all stages of the investigation process and requires attention and emphasis from leaders [17].

3.6 Gaps in the Literature

A number of gaps in the literature have been identified for future research opportunities. It is clear that while theory abounds on investigation models and methods and organisational learning, many more practical evidential studies are required in order to answer some of the questions raised by the authors cited in this review. There have been very few studies undertaken to test the theory and there is little currently to guide practitioners in closing the gap between organisational learning theory and practice following incident events.

3.7 Recommendations for Best Practice

Recommendations for best practice include further empirical studies on: how different groups within organisations learn most effectively; observation of learning in action following events to define opportunities missed; the direct causes and latent conditions for failure to effectively learn from incidents; defining a set of indicators for propensity to learn; how to establish an effective and rigorous process developing remedial actions; study of investigation methods in practice across an industry to gauge effectiveness in reality; development of selection criteria for investigation events; what effective dissemination of information looks like; and environmental conditions and delivery modes for successful knowledge sharing following events.

Also, as noted by Sanne [16] major event investigations would benefit from supporting Social Scientist participation so that the global community can reap the benefit of these windows of opportunity for understanding human factors and the social environments surrounding events.

4 Conclusion

If organisational learning is one of the key accident prevention strategies of the current 'adaptive' age of safety then the safety profession has much work ahead of it to find how to do this effectively. Currently opportunities for this learning are often missed, or not realised fully, so priceless lessons that could save lives go unlearned. The ability to develop true resilience lies in part with being able to understand future risks fully by learning from past events including those that did not result in catastrophic consequences. With a focus on significant loss incidents, industry remains blindsided by these events even though too often there were precursors including near misses, weak signals or abnormal conditions that were either not recognised or given the attention they deserved.

Time and budget constraints, lack of skill or competency to report, select, analyse and investigate events coupled with our increasingly complex socio-technical systems means these preventable accidents will continue unless we adapt our learning models and methods effectively to accommodate all levels of workers within organisations with all their respective attitudes, capabilities, mind sets and degrees of influence.

Further empirical studies around the suggested barriers to effective organisational learning throughout the full lifecycle of incident investigation are urged.

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The Study of Population Evacuation Problems

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Abstract. With the rapid development of society around the world, the population of cities such as Beijing and Shanghai has increased dramatically, and large social activities have been increasing. Safeguarding the legitimate rights and interests of citizens and strengthening public safety is one of the most important problems. Therefore, it is a very important research topic to study the aggregation phenomenon and the evacuation characteristics of the public places, to explore the reasonable group organization and evacuation mode, and to find ways and means to reduce the risk of accidents. When a sudden event occurs in a public place, the crowd is evacuated using the particle swarm algorithm. In addition, the shortcomings of the traditional particle swarm optimization are improved, and the influence of obstacle on individual evacuation path selection is fully considered. Finally, the thermodynamic diagram is used to simulate the model, and the feasibility of the model is verified.

Keywords: Population evacuation · Particle swarm optimization · Obstacle avoidance mechanism · Thermodynamic diagram

1 Introduction

With the rapid development of urbanization and the rapid development of economic society, recreational activities, exhibition activities, sports events, celebrations and other large-scale crowd gathering activities frequently, civil airports, sports venues, squares and other places of public places in the sharp increase The There is no obvious precursor to the occurrence of sudden public events, and there is a sudden and complex. Under normal circumstances, the occurrence of public emergencies can cause significant casualties, social harm and property damage. Over the years, sudden public events have occurred frequently, especially groups of stampede events, in which the case of a major crowded stampede event is shocking:

- November 29, 2010, in Aksu City, Xinjiang Hangzhou Avenue Aksu fifth primary school serious stampede accident, nearly 100 students were injured [1];
- January 14, 2011, India, Kerala, a more serious stampede incident, the accident at least 100 people were killed and dozens of injuries [1];
- February 21, 2011, Mali capital Bamako stadium took place stampede event. According to the data released by the Government, the incident has caused 36 people were killed and 64 injured [1];

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- September 26, 2014 at 2 pm, Kunming Mingtong primary school stampede accident, resulting in 6 people were killed and 26 injured [1];
- December 31, 2014, Shanghai Bund occurred crowded stampede accident. Killing 36 people and injuring 47 others [1];
- On September 24, 2015, 717 people were killed and more than 800 others were wounded by the pilgrims in the Mina area, 5 km east of Saudi Arabia [1].

In order to solve the problem of evacuation, the relevant departments should take safe and feasible emergency measures, not only to evacuate the evacuation of individuals in the environment, but also to make the evacuation process as a whole the overall safety and efficiency. In order to accomplish this goal, it is necessary for the research workers of various disciplines to analyze and solve the problems. These disciplines mainly include geography, artificial intelligence, public safety, computer science, geological exploration and other disciplines [2–4]. The most important thing about evacuation is how to ensure that people evacuate quickly and safely in an emergency and complex environment. Therefore, the problem of group evacuation is more and more concerned by scholars, and has gradually become a hot topic. The research direction mainly includes the movement law and characteristics of the group, how to effectively and safely supervise the group, so as to develop the efficient and scientific and reasonable evacuation method for the evacuation work of the group, and effectively direct and guide the crowd. At present, the research on emergency evacuation at home and abroad mainly includes the establishment of evacuation model and two aspects of simulation experiment. On the one hand, the establishment of evacuation model mainly uses game theory, social dynamics [5], cellular automata [6], fluid dynamics and other methods. The evacuation model was established, and the performance analysis of the model was carried out to study the aggregation, friction and crowding of the crowd in different environments, so as to guide the effective evacuation of the crowd. On the other hand, the study of the evacuation process in the shortest evacuation path, the fastest evacuation flow and other issues. However, this research needs to be based on the nature of the different road network analysis, such as the static characteristics of the road network, the dynamic characteristics of the crowd and the vehicle and so on. Therefore, most of the current evacuation measures are to ease the crowd in emergency situations, and the hidden crisis for the characteristics of the crowd is lack of relevant research. Urgent evacuation of the crowd is important, but effective prevention and reduction of the occurrence of an emergency is particularly important. How to effectively manage the complex, large crowd in large public facilities, to prevent the occurrence of an emergency is of great significance.

In this paper, the particle swarm optimization [7, 8] is used to abstract and model the evacuation of people in the evacuation scene in emergencies. Each individual is abstracted into particles, and the selection of the optimal value of the particle through the particle Explore the optimal information to change the velocity vector of the particle and keep it near the safe location and evacuate.

2 Particle Swarm Optimization

Particle swarm optimization is a stochastic optimization algorithm for population, proposed by Kennedy and Eberhart. The algorithm has been widely concerned. Rada et al. have studied the algorithm's synchronization and neighborhood size problem. Particle swarm optimization produces a new evolutionary algorithm for the study of foraging behavior of birds. The researchers found that in the process of predation of birds or fish, the group in accordance with a cooperative way, through their own continuous access to information, to adapt, and then obtain information, and then adapt, and constantly adjust their own speed and direction, the whole process is Its optimized process. Use the vector group $(x_i^m, v_i^m, pbest_i)$ to represent the particle, use x_i^m to represent the position of the particle itself, use v_i^m to represent the current direction, use $pbest_i$ to represent the best position of the search itself, all the particles by evaluating a function $f(x)$ to determine the fitness value Change the value. Each particle has a memory function that can remember its own optimal position and follow the surrounding optimal particles. In the standard of Particle swarm optimization, the particle's position and velocity are updated as follows:

$$X_{id}^{m} = X_{id}^{m-1} + V_{id}^{m-1}. \tag{1}$$

$$V_{id}^{m} = WV_{id}^{m-1} + c_1 r_1 \left(pbest_{id} - X_{id}^{m}\right) + c_2 r_2 \left(gbest_{id} - X_{id}^{m-1}\right). \tag{2}$$

In the formula: X_{id}^m represents the position of the population; V_{id}^m indicates the speed at which the person moves; $pbest_i$ is the best position for the i particle: $gbest_i$ is the best bit value for the population; c_1 and c_2 are the acceleration factors, respectively, indicating the particle arrives at the best position Good position of the acceleration weight; r_1 and r_2 are the random numbers between 0 to 1; W is expressed as an inertia factor. The formula (2) shows that the particle velocity update can be divided into three parts: the first part shows the velocity inertia of the particle i, which can form a better balance between the global search and the local search. The second part shows the optimal position of the individual The effect of velocity, which determines the ability of the particle to be locally searched; the third part reflects the effect of the optimal position of the population on the speed, which reflects the communication within the group.

3 Avoidance Mechanism

3.1 Evaluation Function

In the classic Particle Swarm Optimization, the particle only focuses on the final target position and finds that the individual moves directly to the point after the target position and does not take into account the limitations of the obstacle, which is negligible in the evacuation process. In reality, pedestrians should consider each step of the escape route choice, in which static obstacles and other pedestrians will have an impact on the choice of the path, the introduction of the evaluation function to simulate obstacles and other pedestrians on the impact of pedestrians:

$$\cos\ t(p,q) = \exp\left(-\left(\frac{(p-q)^2}{\left(\sigma_p+\sigma_q\right)^2}\right)\right). \tag{3}$$

In the formula (3), p represents a particle, q represents an obstacle, including other particles and static buildings, σ_p is expressed as a particle radius, σ_q is expressed as an obstacle coverage. The evaluation function here refers to the impact of obstacles (including other pedestrians and buildings) in the process of pedestrian movement. Considering the evaluation function [9], the objective function can be set to:

$$F_{obj}(p) = c_{obs} \times \max(\cos\ t(p, o)) + \frac{1}{\cos\ t(p, g)}. \tag{4}$$

In the formula (4), o refers to a collection of all obstacles, g is expressed as a particle-oriented and standard position, c_{obs} is expressed as a weight parameter that adjusts the relationship between the obstacle and the target. The setting of the objective function adds the cost function mechanism, which can more effectively and effectively simulate the path selection in the process of pedestrian orientation.

3.2 Judgment Mechanism

The introduction of the value factor in the evaluation function makes the particles can realize the avoidance of obstacles and other pedestrians to a certain extent. For the more realistic simulation of the actual situation, we introduce the following judgment mechanism [10] on the basis of the above evaluation function, Whether the new position of the trend conforms to the common sense rule and determines whether the new position is accepted as follows:

$$\text{prob}(f) = 1 - \frac{f}{e^{-k}}. \tag{5}$$

In the formula (5), it is the value of the new position, it is constant, used to control the particles near the obstacles and other pedestrian behavior, the function can better prevent the collision between particles. In order to simulate pedestrian obstruction and other pedestrian route selection, if the new location is not accepted, in the original position on the basis of ±15° angle to change the search for the appropriate location. At the same time as the distance and obstacles and other pedestrians close to the distance gradually reduced, the impact of obstacles on the speed as follows:

$$speed = speed \times (1 - \cos\ t(p)). \tag{6}$$

4 Simulation and Analysis

The simulation is evacuated in the form of thermodynamic diagram [11], which shows the geographical area of the population in a special highlight. According to the above algorithm and process, simulation and analysis. In a block size of 10 m × 10 m square, divided into 100 square small area, with red dot. The degree of darkness in each small area represents the number of individuals in the area, that is, the density, the total number of individuals is 500. The degree of light and dark corresponding to the initial density and individual thermal diagram shown in Fig. 1.

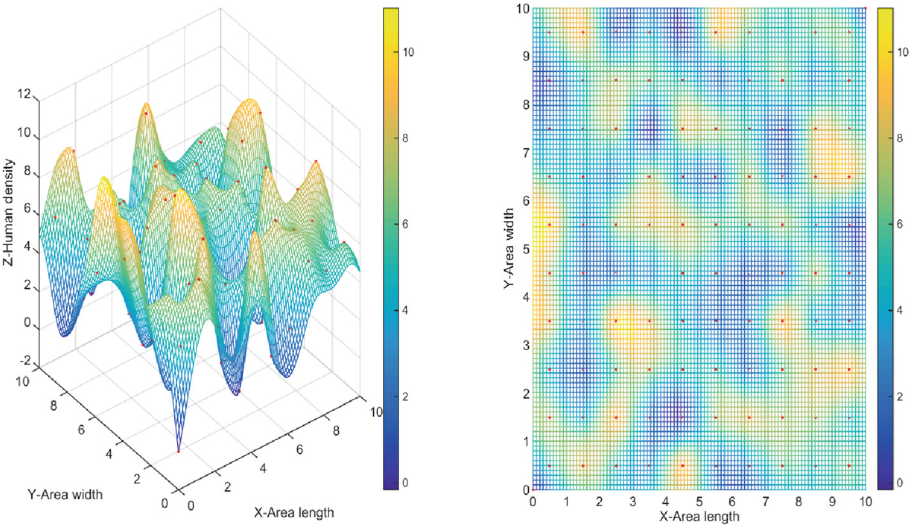

Fig. 1. Population density initial distribution.

In Fig. 1, the x and y axes represent the area range, and the z-axis represents the individual density (i.e., the number of individuals) in each region. Brightness color of the light and dark corresponding to the size of the individual density of each region, the greater the density the more bright colors, and vice versa the darker.

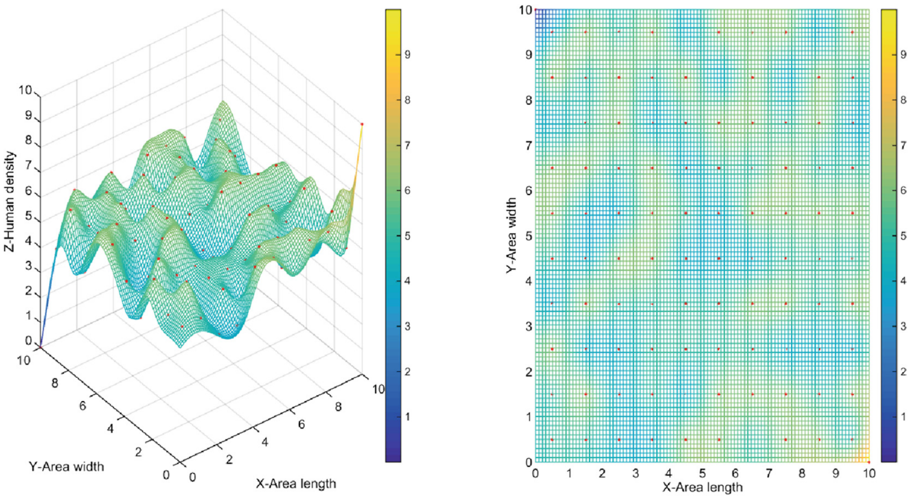

Fig. 2. Population density after evacuation.

In the particle swarm optimization and avoidance mechanism, the density of large areas of the individual flow to the density of small areas, effectively alleviate the pressure of the highlighted area, the density of the dispersion is more average, effectively reducing the incidence of accidents, to protect people The safety of life. as shown in Fig. 2.

5 Conclusion

Effective evacuation of the crowd is an important link in the protection of social security, in recent years due to evacuation and the occurrence of stampede more and more accidents. Through the real-time satellite came the thermodynamic diagram to monitor the gathering of crowded population, once the bright areas immediately into the evacuation process, the use of communications devices highlight the area to evacuate. The evacuation model is combined with particle swarm optimization and thermodynamic diagram, and the improvement and optimization of the evaluation function and the obstacle avoidance mechanism are carried out. The feasibility of the model is verified by simulation. In the future study, we will increase the evacuation guidance factors, group characteristics and dynamic disaster model in the model, and further study the evacuation process of the crowd under complex scenes such as disasters. So as to provide a more in-depth and detailed theoretical basis for the evacuation management of the crowd.

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