Lecture Notes in Networks and Systems 262

Pedro M. Arezes
Ronald L. Boring *Editors*

Advances in Safety Management and Human Performance

Proceedings of the AHFE 2021 Virtual Conferences on Safety Management and Human Factors, and Human Error, Reliability, Resilience, and Performance, July 25–29, 2021, USA

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Editors

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Preface

This volume combines the proceedings of two affiliated conferences of the 2021 Applied Human Factors and Ergonomics Conference: the 8th International Conference on Safety Management and Human Factors, chaired by Pedro Arezes of University of Minho, Portugal, and the 5th International Conference on Human Error, Reliability, Resilience, and Performance, chaired by Ron Boring of Idaho National Laboratory, USA.

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. The discipline of 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 and in society at large. 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 are fundamental to the creation of both 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.

The International Conference on Human Error, Reliability, Resilience, and Performance (HERRP) is unlike other risk conferences, which have tended to be centered largely on probabilistic risk of hardware systems. HERRP has a decidedly human factors' angle. The research presented explores human error from a human factors perspective, not solely a risk modeling perspective.

The purpose of the HERRP conference is to bring together researchers and practitioners from different fields who broadly share the study of human error. The HERRP conference is intended to serve as an umbrella for human error topics by providing an annual forum for otherwise disjoint research efforts. As such, the conference is intended to complement but not replace existing specialized forums

on particular facets of human error. The HERRP conference is distinctly interdisciplinary, encouraging the submission of papers in focused technical domains that would benefit from interaction with a wide human factors' audience. Additionally, the HERRP conference aims to provide a yearly, high-quality, archival collection of papers that may be readily accessed by the current and future research and practitioner community.
Nine sections are presented in this book as follows:

Advances in Human Error, Reliability, Resilience, and Performance

1. Resilience and Human Performance
2. Human Reliability Analysis
3. Human Error, Reliability, Resilience, and Performance in Aviation
4. Organizational Effects on Human Performance

Safety Management and Human Factors

5. Digital Safety
6. Risk Exposure and Assessment
7. Safety and Human Factors
8. Safety, Prevention Management, and Training
9. Safety Perception and Safety Culture

Sections 1–4 cover topics related to resilience, reliability, and human performance and human error, while Sections 5–9 cover topics related to safety, prevention management, training, and safety culture. Thematically, the two conferences complement each other. The former focuses on prevention and management of risk, while the latter discusses causes of human error.

To err is human, and human error is consistently implicated as a significant factor in safety incidents and accidents. Yet, as pervasive and important as human error is, the study of human error has been fragmented into many different fields. In fact, in many of these fields, the term "human error" is considered negative, and terms such as human variability and human failure are preferred. Across differences in terminology and approach, the common link remains an interest in how, why, and when humans make incorrect decisions or commit incorrect actions. Human error often has significant consequences, and a variety of approaches have emerged to identify, prevent, or mitigate it. These different approaches find a unified home in this volume covering a wide spectrum of safety and risk topics.

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

We wish to thank the authors for their exceptional contributions and to scientific advisory board for encouraging strong submissions:

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July 2021

Pedro Arezes
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Contents

Resilience and Human Performance

Examination of Design and Human Factors Supporting Sensemaking, Resilience and Performance in the Ship Accident Helge Ingstad in Norway

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Abstract. We examine design and Human Factors supporting sensemaking, resilience and performance on the bridge of the frigate HNoMS Helge Ingstad that collided with the tanker Sola TS in 2018. We are presenting a framework to evaluate the design based on a system perspective. The frigate was a modern ship, with seven seamen on the bridge, performing operations during night. The officer of the watch considered Sola TS as a part of a land-based installation. The officer did not get clear indication from supporting systems on the bridge that Sola TS was a moving ship. The workload on the bridge was high with many alarms, officers in training, and communication through VHF. No personnel fatalities, but the frigate sank. The cost of a new frigate is estimated to be 1400 Mill USD. The accident analysis benefits from the sensemaking perspective, the design of bridge systems did not support reliable sensemaking.

Keywords: Human Factors · Sensemaking · Resilience

1 Introduction

In this paper we examine design and Human Factors (HF) supporting sensemaking, resilience and performance on the bridge of the frigate HNoMS (His Norwegian Majesty's Ship) Helge Ingstad (HI or Helge Ingstad) that collided with the tanker Sola TS in the Hjeltefjord at 04:01:15 on November 8th, 2018.

The traffic in the Hjeltefjord were under surveillance by the Fedje Vessel Traffic Service (VTS). Three other ships were in the vicinity of Helge Ingstad and Sola TS, mowing towards Helge Ingstad on the port side. Sola TS approached on the starboard side. The key actors were onboard Helge Ingstad, Sola TS and the VTS.

The frigate was a modern ship, with seven seamen on the bridge, performing normal operations in a fairly calm environment, during nighttime. The officer of the watch (OOW) was in charge from 03:56 and considered the tanker Sola TS a part of a land-based installation on the coast. The OOW did not get clear indication from the chart system

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on the bridge, ECDIS (Electronic Chart Display and Information System), that SOLA TS was a moving ship. The mental workload was high on the bridge with many alarms, officers in training, and radio communication through VHF (Very High Frequency). The environment did not support common and reliable sensemaking among the involved actors. No personnel fatalities were recorded as a consequence of the collision, but the frigate Helge Ingstad sank. The cost of the frigate was initially 500 Mill USD, the cost of a new frigate is estimated to 1 400 Mill USD, making the total cost of the accident 1 900 Mill USD.

We have explored the accident based on a system view and best practices of Human Factors investigations as described in [1]; describing events as they evolved during the accident; the perceptions and sensemaking among the actors during the events and reflections on root causes of the accident with discussion of design issues. The central factors are:

- the actors involved in the accident, i.e., Helge Ingstad, TS Sola, Fedje Vessel Traffic Service (VTS) with technology, humans and organization.
- design, Human Factors, sensemaking and resilience of the system surrounding the Helge Ingstad accident, i.e., environment (with infrastructure), practices, regulation and culture.

The paper will in particular focus on the sensemaking and systemic factors on the bridge of Helge Ingstad).

2 Key Definitions, Approach and Methods

Design is a key issue to support safe operations and avoid accidents. This view is supported in [2], where it is stated «Human Error? – No, poor Design». Design decisions as a cause of accidents are seldom sufficiently explored, even though it is estimated that design are the root causes of approximately 50% of accidents, [3, 4]. In this paper we have explored design issues based on standards for human factors design such as ISO standards [5] and [6]. The quality assurance of the design process has been based on [7], a best practice guideline that is being used in the industry [8] with good results. We have focused on the design of the control systems (CS), at the VTS and the ships (i.e., the bridge with information and CS supported by the physical layout), however our main focus has been the bridge at HI.

We define Human Factors (HF) as "*the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance*", [9]. Three key areas of HF are Cognitive issues (Perception, Task analysis, mental workload, situational awareness), Ergonomic issues (workplace layout, working environment, work position), Organisational issues (Responsibility, Work procedures, Communication, Crew Resource Management, Team collaboration) from [10, 11].

Sensemaking is a continuous process. The HI accident happened while the actors performed regular daily operations with necessary adaptations to ensure normal performance. The discussion of the accident is based on a sequential documentation of what actually happened between the different actors, such as described by the STEP method, [12]. The next step is to use the perspective of sensemaking, trying to understand how the different actors understood the situation by their actions. Then we try to understand and analyze the actions based on cognitive, organizational and ergonomic factors. The sensemaking of the actors are taking place based on the whole system, impacted by the design of the information systems, the training of the involved actors and the surrounding environment. The sensemaking concept builds on the initial descriptions from Weick, [13]. We are using sensemaking as a dynamic, iterative process of observing, orienting, and acting in a social setting, creating a shared understanding. Sensemaking is seen as a process that is prompted by violated expectations, that involves both attending to and bracketing cues in the environment with the aim to create intersubjective meaning through cycles of interpretation and action, enacting an ordered environment from which further cues can be drawn, [14]. We are trying to understand the actual sensemaking from the perspective of credibility, transferability and reliability based on terminology from [15]. We use credibility to denote to which extent the systems enable a match between reality and ongoing individual sensemaking i.e., having sufficient cues to match reality ensuring meaningful human control. We use transferability in relation to the existence of common sensemaking between the different actors, i.e., if situational assessment can be transferred between the actors. Reliability describes the match between the actors sensemaking and reality that are observed.

Resilience, as the ability to handle the unexpected, can be an important property in handling a stressful situation or an accident. Resilience (RE) is defined as "*the intrinsic ability of a system to adjust its functioning prior to or following changes and disturbances, so that it can sustain operations even after a major mishap or in the presence of continuous stress*", [16]. Discussing resilience of operations, some key issues are the ability to have redundant safety systems of safety critical operations (i.e., ability to control position from several systems) and the ability to reduce complexity (i.e., establish situational awareness at a glance).

2.1 Approach and Methods

We have based our approach on an analysis of the accident report, [17], exploring the timeline of the actions supported by interviews of involved actors to discuss the findings. The aim of the accident analysis, [17], was to understand and learn from the accident, not to place blame. They used perspectives from sensemaking and Situational Awareness (SA), as defined and used in [18, 19].

We have also performed a literature review to explore the role of bridge control systems in maritime accidents [20]. Based on the accident report, the interviews and literature review we have examined the design based on principles from the CRIOP method, i.e.:

A. Job Organization, Procedures, Work Descriptions and Training- covering HF organization
B. Control and Safety Systems – covering HF Cognitive issues
C. Layout and Working Environment – covering HF ergonomics.

3 The Timeline of the Accident

In the following narrative we have described the timeline of the HNoMS Helge Ingstad accident as it evolved, based on the three key actors (HI, SOLA TS and VTS), from [17]. Then we have performed an evaluation of the design.

VTS timeline on the night of the accident

- 02:38 The VTS got a call from Helge Ingstad informing that they would enter the area of the VTS.
- 02:50 Helge Ingstad entered the area, but the VTS did not plot Helge Ingstad on their radar, (i.e., leading to poor ability to share information between actors)
- 03:45 the VTS acknowledged that Sola TS departed. Three ships going north and two ships (Helge Ingstad and Dr No) going south – in addition to Sola TS. Helge Ingstad were poorly identified due to no automatic information system (AIS).
- 3:59 the VTS discovered a possible collision vector between Sola TS and Helge Ingstad. The VTS communicated to Sola TS that it could be Helge Ingstad.
- 04:00:44 the VTS told Helge Ingstad that they had to do something - but no direct commands from the VTS, no closed loop communication, or emergency keywords were used, i.e., poor transfer of understanding between the actors.
- **04:01:15 collision between Helge Ingstad and SOLA TS**

The VTS had not a credible understanding of the situation initially, did not manage to transfer perception of the situation with urgency to Helge Ingstad, and did not take control through emergency procedures.

SOLA TS timeline on the night of the accident

- 03:37 Sola TS left the brightly lighted Sture Terminal.
- 03:45 Captain and the pilot at the bridge informed the VTS about their departure. (ECDIS information updated later and not communicated to Helge Ingstad at departure, supporting a perception that the ship was anchored at Sture terminal.)
- 03:52 the bridge saw a ship coming towards Sola TS (i.e., Helge Ingstad).
- 03:58 Sola TS asked the VTS about the ship (Helge Ingstad).
- 03:59:56 communication between Sola TS and HI/OOW, Sola TS tried to communicate an impending collision
- **04.01.15 collision with Helge Ingstad**

SOLA TS did not manage to get credible communication with Helge Ingstad.

Helge Ingstad timeline on the night of the accident

- 03:45 to 03:53 briefing of new OOW. SOLA TS were identified as an object as a part of the Sture Terminal.
- 03:47 to 04.01 the bridge handled 12 alarms; this is almost one alarm each minute. This was alarms related to objects that the bridge was aware of and thought they could control, no alarms from Sola TS that they collided with.

- 03:53 responsible OOW changed. Sola TS were visually observed, seen as a part of the land based Sture Terminal and not as a ship by some personnel on the bridge. The OOW had a perception that Sola TS was the Sture Terminal. Large part of Sola TS (200 m) was not lighted – it was difficult to see Sola TS. This perception and understanding were not communicated and shared on the bridge, verbal clues and information sharing were a challenge due to the noise level. No common mental model among the actors on the bridge.
- 04:00 the OOW used the VHF radio not close to ECDIS/Radar, thus visual clues could not be shared between systems. The OOW reiterated to SOLA TS that they were close to land (actually the bright part of Sola TS). No commands from VTS.
- **04.01.15 collision with Sola TS**

Poor possibility/systems to check credibility and support transferability of sensemaking at Helge Ingstad.

At HNoMS Helge Ingstad, the process of sensemaking, including observing, orienting, and acting were based on missing credible information from the supporting systems. The cues from the systems were difficult to coordinate and synthesize due to fragmented information. The communication between VTS, SOLA TS and Helge Ingstad had missing focus on transferability and closed-loop communication, i.e., they did not manage to have a shared perception of the situation or manage to establish "a shared perception/understanding at a glance". The cues being used by the OOW were not redundant and did not challenge the perception that SOLA TS were a part of the coast/Sture Terminal.

4 Evaluation of Design Issues

Evaluation of design is based on principles such that design is based on a systematic task analysis (focusing on safety critical tasks). Key design principles are:

- HF Organization and manning is based on task analysis that helps to decide what should be computer systems vs human based operations. Task analyses decides how operations are organized (responsibility) and how procedures are developed. Task analysis are used as a basis for workload analyses (physical and mental workload) and workload is assessed to avoid stress or complacency during critical tasks.
- HF cognitive issues such as Human Machine Interfaces are designed to support tasks and credible sensemaking (i.e., sufficient cues to enable control of information through several clues based on independent sources). Alarms are designed to handle deviations, taking into accord human limitations. As an example, that the operators cannot handle more than six alarms each hour as specified by [21].
- HF ergonomics such as physical layout are designed to support tasks (i.e., arranging equipment together to ensure efficiency and support of sensemaking) and support good working environment and communication (low noise).

Going through the accident report supplied with interviews, the following issues are explored: A. Job Organization, Procedures, Work Descriptions and training; B.Control and Safety Systems; C. Layout and Working Environment.

A. **Job Organization, Procedures, Work Descriptions, training**
It was not documented that the organization and manning on the bridge were based on a systematic task analysis. The class of ships (five ships) that HI was a part of, got an updated VHF radio. At HI the VHF was installed (in a corner) without a systematic task analysis. The consequences of this installation were poor visibility to Radar and ECDIS while using the VHF. During installation at another ship in this class, an experienced officer was on the bridge with knowledge of tasks and managed to get the VHF radio placed close to the Radar and ECDIS in order to give the user a good view of these systems during VHF use (i.e., task-oriented design). In the minutes before the collision the OOW were using the VHF and talking to Sola TS and did not have easy access to the radar and ECDIS. (This was not reported in the accident report).
The manning of the bridge had been influenced by a high-level strategy called LMC-Lean Manning Concept, implemented primary to reduce costs. There was no workload assessment of navigating at night, with many alarms, performing training at the same time as performing safety critical tasks such as navigation.
Work procedures matching crew selection were not optimal related to tasks at night. In the AIB report it was mentioned that three of the seven persons on the bridge had no visual impairment, i.e., some of the crew on the bridge had some sort of visual impairment. It is uncertain if this impacted the accident, but sensemaking could have been impacted, and these facts should have been used when planning the night-time operations.
To summarize, there was poor task analysis to ensure adequate sensemaking support of critical tasks, poor crew selection/planning and missing workload analysis to ensure that credible sensemaking was taking place.

B. **Control and Safety Systems; HF Cognitive issues**
In [17] it is mentioned that the bridge handled 12 alarms on the bridge the last 14 min, this is almost one alarm each minute. (This was alarms of objects that the bridge was aware of and thought they could control, no alarm from the proximity of Sola TS that they collided with). This is a high mental workload, directing sensemaking and focus to non-critical areas and reducing the credibility of sensemaking. The alarm standard [21], specifies that the maximum number of important alarms that can be handled is six alarms in one hour, i.e., 10 min between each alarm. Thus, the alarms were not designed in accordance with acceptable HF standards.
We have also performed a review of 19 maritime accident reports related to control systems on the bridge, [20]. The poor quality, poor alarm philosophy and poor user friendliness of the ECDIS systems were highlighted in the accident reports. There was widespread de-selection of automated functions in ECDIS that is indicative of wider problems; and the system is not used as expected by the regulators or equipment manufacturer. ECDIS is not utilized effectively as navigation aid and audible alarm often disabled. ECDIS may give many alarms and overwhelm the watchkeeper, and we found poor understanding of the system and relationship of alarms. The chief inspector MAIB (Marine Accident Investigation Branch) said in one of the reports: "*this is the third grounding investigated by the MAIB where watchkeepers' failure to use ECDIS properly has been identified as one of the causal factors. In 2014 there are over 30 manufacturers of ECDIS equipment, each with*

their own designs of user interface, and little evidence that a common approach is developing".
To summarize, there was poor alarm design to help to reduce mental workload and support critical sensemaking. The poor general quality of ECDIS reduces understanding of the surrounding environment of the ship. The alarm overload and the poor quality of the ECDIS system challenged credible sensemaking.

C. **Layout and Working Environment; HF physical ergonomics**
The ergonomics of the working environment is important for sensemaking to take place. The environment is influenced by factors such as noise, lightning level, and temperature. Team communication on the bridge is dependent on coordinating mechanisms such as shared mental models, closed-loop communication, and mutual trust [22]. To support communication, the noise level should be acceptable. In [17], it is pointed out:" Bridge *ventilation system is so noisy that it is difficult for the bridge team to communicate in a normal manner. Excessive levels of noise interfering with voice communication, causing fatigue and degrading overall system reliability, shall be avoided. (noted during visit on-board)"*. In [23] they pointed out that "*All vessel classes, except the coast guard vessels, had noise levels exceeding the Royal Norwegian Navy (RNoN) standard's recommended maximum noise levels.*" The background noise level should be below 45 db when performing safety critical tasks [7], but the noise level was higher at Helge Ingstad, impacting sensemaking.

One adaptation on the bridge of HI that was mentioned, was that some of the lights on the bridge had been taped over in order to preserve "the night vision" of the officers on the watch., i.e., indicting poor consideration of user needs and user centered design for operations at nighttime. To summarize, the working environment was not optimal regarding noise and lightning, issues that challenged credible sensemaking.

5 Conclusions – Support of Sensemaking

Examination of the accident report, interviews and literature review revealed that design and Human Factors (HF) did not sufficiently support sensemaking, resilience and performance on the bridge at HNoMS Helge Ingstad. The poor user quality of ECDIS systems seems to be a recurring challenge.

The poor design was a significant root cause of the accident. Task based design to support cognition, organizational structure and layout of the Helge Ingstad bridge were missing which reduced credible sensemaking. As an example, the positioning of the VHF radio at HI influenced the reliability of sensemaking. The local user adaption of placement of the VHF in other ships was not reported in the accident report and is new information.

Sensemaking is a beneficial perspective in accident analysis, helping to understand what the actors actually observed, made sense of and which actions they took during the accident. The sensemaking is on-going process and helps to create understanding and learning instead of placing blame. Thus, the accident and this paper report benefited from the sensemaking perspective, illustrating that the design of the environment and the bridge systems at HNoMS Helge Ingstad were poor and did not support reliable sensemaking.

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Trait Interindividual Differences in the Effectiveness of Modafinil

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Abstract. *Purpose*: To optimize the usage of modafinil as a cognitive enhancer and increase safety and effectiveness, we sought to assess the trait-characteristic of modafinil-sensitivity.

Methods: 11 healthy participants (age = 21 ± 2 yr) were tested on 2 separate occasions during which they were sleep deprived for one night. During one trial they received 2 × 200 mg modafinil (i.e. EXP); during the other they received 2 × a placebo-capsule (i.e. CON). Physiological (e.g. heart rate and blood pressure), subjective (e.g. sleepiness and mood state) and behavioral (e.g. psychomotor vigilance task) measures of sleep-wake regulation were followed up.

Results: Both PVT performance and perceived sleepiness were significantly improved in EXP at 2AM and 4AM during the sleep deprivation-night, compared to in CON. Additionally, an ICC of 0.90 for the delta (CON – EXP) in non-adjusted reaction time was observed.

Conclusion: Stable and robust interindividual differences in modafinil-sensitivity are clearly present across day and night.

Keywords: Psychostimulant · Human performance · Interindividual differences

1 Introduction

Research in strategies to mitigate the impact of disturbed sleep/wake regulation on human functioning has increased in importance in the last decades. This does not have to be surprising, as the impact of disturbed sleep/wake regulation (e.g. sleep restriction/deprivation) on human functioning has been shown to be significant and substantial. The use of psychostimulants is one strategy that is used to counteract the impact of

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disturbed sleep/wake regulation [1–3]. Within the possible psychostimulants that could serve to positively impact sleep/wake regulation, modafinil (Provigil; 100–200 mg) is one of the most used. Initially (i.e. in 1998), modafinil was a medical drug used in the treatment of narcolepsy [4]. Besides its usefulness to treat narcolepsy, the usage of modafinil to counteract non-disease-related sleepiness and enhance cognitive performance gained rapid interest [5]. Modafinil parallels the effects of d-amphetamine in combination with relatively almost no reports of side effects [3, 5].

Up to date, it appears the usage of modafinil to counteract the negative effects of sleep deprivation, improve concentration, increase alertness, focus and/or mental stamina (i.e. all situations that are unrelated to any disease) is widespread implemented in multiple contexts [3, 6]. Moreover, the usage of modafinil appears to still go hand in hand with a minimal occurrence of (minor) side effects [3, 6]. However, in specific situations (e.g. during work-related activities) even these minor side effects (e.g. headache, diarrhea, anxiety) might however be of importance. Sensitivity to modafinil seems to be individually dependent [7–9]. Moreover, these interindividual differences in the response to modafinil-usage do appear to be replicable and robust in time [9, 10], and thus appears to be trait-like [11]. Individualizing the modafinil-usage/dosage according to this trait would result in further increasing the safety and effectiveness for both the individual and society, as individuals for who modafinil is ineffective would not take in modafinil unnecessarily.

Therefore, to optimize the usage of modafinil as a cognitive enhancer and fatigue countermeasure, the current project aimed to investigate its effectiveness on an individual level. To reach this aim, physiological, psychological and behavioral measures of sleep-wake regulation were followed up in one-night-sleep-deprived individuals, during the day and night of their sleep deprivation, and during the day following on their sleep deprivation. Based on the results of Bodenmann et al. [7, 8] we hypothesized that two-time 200 mg modafinil would counteract the sleep-deprivation-associated decrease in human functioning in individuals that are modafinil-sensitive.

2 Methods

2.1 Participants

An a priori sample size calculation based on the results reported in the study of Caldwell et al. [10] (reported effect size of condition x time interaction in terms of Psychomotor Vigilance Task (PVT) performance = 0.378) showed that a total of 10 participants was needed to observe the effect of modafinil on human functioning. Eleven participants volunteered to participate in the present study (1 female, 10 males; mean $\pm$ SD, age = 21 $\pm$ 2 yr). None of the participants had any known mental or somatic disorder. Each participant gave written informed consent before the study. All participants were given written instructions describing all procedures related to the study but were naive of its aims and hypotheses. Participants were informed that the purpose of the study was to investigate the effect of two (modafinil and slow-release caffeine) potentially performance-enhancing substances and were debriefed after completing all trials.

2.2 Experimental Protocol

The subjects were asked to return to the lab for 3 consecutive trials (cross-over design). The first trial was a 60-min familiarization trial to get to know the online software, the questionnaires and to avoid learning effects in the cognitive task. In the familiarization trial descriptive data of the participants was gathered and all questionnaires and cognitive tasks were completed/performed once. Preceding the beginning of the familiarization trial, subjects had to read and sign the informed consent to participate. The familiarization trial took place in the morning (i.e. 10AM) of day 1 of the first interventional trial.

The familiarization trial was followed by 2 interventional trials in a randomized counter-balanced order. Subjects performed the two interventional trials (i.e. modafinil-trial (EXP) and calcium lactate-trial (CON)) within a period of 3 weeks. This because of the 1-week washout period between both interventional trials. Participants and researchers involved in data collection, outcome assessment and statistical analysis were blinded to the intervention. Each interventional trial took 3 days. On day 1 of each 3-day trial, subjects first performed their work-related duties as normal. After their normal day of work, subjects reported themselves online in a virtual meeting at 8PM. After this first virtual meeting two more virtual meetings were held during each 3-day trial, one at 10PM of day 1, and one at 8:30AM of day 2 (see virtual meeting). Before starting a trial, compliance with instructions (see Restrictions and prohibitions for the subjects) was assessed with a checklist. Throughout every 3-day trial, subjects performed a sleep deprivation protocol combined with 15 online test protocols at specific time intervals (see sleep deprivation protocol and online test protocol time intervals). To perform these online test protocols, subjects were asked to perform their test-intervals seated in a comfortable chair in a sound-deprived room with as little distractors present as possible (i.e. no time indicators, no smartphone). To determine the effect of modafinil supplementation on sleep deprivation-induced psychological, physiological and behavioral performance alterations, every online test protocol began with a medical questionnaire (see medical questionnaire), followed by the Profile of Mood States (POMS; see POMS) to assess mood and a Psychomotor Vigilance Task (PVT; see PVT) to assess cognitive performance.

Virtual Meeting. Within a virtual meeting, participants checked their basic physiological parameters under the guidance of a medical doctor and took in their first two tablets of the eventual four that they had to take in during each interventional trial. Basic physiological parameters encompassed: heart rate (HR; Rossmax AC1000F), blood pressure (BP; Rossmax AC1000F), body temperature (Tbody; home-available thermometer) and respiration rate (RR; self-count in a 30s time-interval). In addition, participants can ask questions or indicate possible perceived side-effects.

Sleep Deprivation Protocol and Online Test Protocol Time Intervals. Both interventional trials (EXP and CON) took 3 days to complete. Concerning the sleep deprivation protocol, participants had to sleep deprive themselves during the first night of the 3-day trial. In terms of the online test protocol, participants had to perform this protocol multiple times (i.e. 15 times; Day 1: 10am, 8pm, 10pm and 12pm; Day 2: 2am, 4am, 6am, 8am, 12am, 4pm and 8pm; Day 3: 8am, 12am, 4pm and 8pm). All online test protocols were identical to one another and encompassed a medical questionnaire (see medical questionnaire), followed by the POMS (see POMS) and a PVT (see PVT).

Medical Questionnaire. In the medical questionnaire participants were asked to self-assess their HR, BP, Tbody and RR like they were instructed during the first virtual meeting and fill out this information in the foreseen fields. Subsequently, they were also asked whether they had perceived any side-effects (e.g. headache, palpitations, hyperventilation, diarrhea and anxiety). Afterwards, they were asked to fill out three Visual Analog Scales (VAS): a mental fatigue-VAS (MF-VAS), a physical fatigue-VAS (PF-VAS) and a sleepiness-VAS.

POMS. The POMS - SF [12] contains six scales that assess different characteristics of mood: anxiety, depression, anger, vigor, fatigue, and confusion (disappointment). Each of the scales is measured using 5 to 8 items on a Likert scale from 0 to 4. Each state is measured on a scale of 0 to 4 which is calculated by summing the scores of the items in each state and dividing that score by the number of items.

PVT. The PVT [13] measures the rapidity to respond to a certain stimulus by pressing the space bar when the stimulus appears. The visual stimulus appears at random intervals (2, 4, 6, 8 or 10 s) and the task lasts for 10 min (i.e. 20 blocks of ~30 s, in each block of 30 s all inter-stimulus intervals are used in a random order). Optimal reaction times are between 200 and 400 ms (i.e. Optimal Response Domain; ORD). To assess performance on the PVT both adjusted (only taking into account the responses within the ORD) and non-adjusted reaction time (RT) were taken into account, as well as accuracy (ACC; i.e. percentage of responses within ORD), limit responses (i.e. responses within 400 to 500-ms time zone after stimulus presentation) and lapses (i.e. responses 500 ms after stimulus presentation).

Restrictions and Prohibitions for the Subjects. Subjects were asked to refrain from alcohol, caffeine and any other psychostimulant intake while participating in the study. The day before each experimental condition, the subjects were expected to sleep according to their normal sleep pattern, refrain from the consumption of caffeine, alcohol and not to practice vigorous physical activity. In addition, subjects were asked to have a similar meal and cognitive load on day 1 of each experimental condition. The use of any kind of medicinal products during and between the trials was prohibited. If subjects could not meet these standards they were excluded from the study.

2.3 Statistical Analysis

All data are presented as mean ± SD unless stated otherwise. To specifically assess the acute effect of modafinil, only the first ten time-intervals of both EXP and CON were taken into account. The Shapiro–Wilk test was used to test the normality of the data. Sphericity was verified by the Mauchly's test. If data were not normally distributed (i.e. POMS depression, confusion, tension, anger and fatigue subscale), non-parametric Wilcoxon tests were used to observe the effect of condition. All other parameters were normally distributed or normally distributed after a square root transformation (i.e. ACC was subtracted from a constant factor [100.1] and subsequently square root transformed; amount of limit-responses and of lapses were square root transformed). The effect of condition and time on all normally distributed parameters was assessed by a two-way repeated-measures ANOVA. If significant interaction effects were observed, subsequent paired-samples t-tests were performed to elucidate the main effect of condition in each time-interval. The stability of interindividual differences for the delta score (CON-EXP) of non-adjusted RT and sleepiness was quantified with the intraclass correlation coefficient (ICC), which was calculated as the between-subjects variance divided by the sum of the between- and within subjects variances. For further information on this statistical analysis see Tucker et al. [14]. Significance was set at <0.05 for all analyses, which were conducted using the Statistical Package for the Social Sciences, version 27 (SPSS Inc., Chicago, IL).

3 Results

3.1 Modafinil and Cognitive Performance

In terms of performance on the PVT, condition and time interacted with each other in adjusted and non-adjusted RT, ACC and lapses ($p \leq 0.033$; See Table 1). PVT-performance significantly deteriorated in CON compared to EXP at the 2AM ($p \leq 0.035$), 4AM ($p \leq 0.023$), 8AM ($p \leq 0.044$; specifically for adjusted RT this was non-significant) and 4PM ($p \leq 0.049$; specifically for the amount of limit-responses this was non-significant) time-interval in almost all these PVT performance variables (i.e. adjusted and non-adjusted RT, ACC and lapses). The only performance-variable where no interaction effect of condition and time was present was the amount of limit-response.

Table 1. PVT performance throughout a night of sleep deprivation and the day after (mean ± SD).

		Day 1				Day 2					
		10am	8pm	10pm	12pm	2am	4am	6am	8am	12am	4pm
Adjusted RT (ms)	EXP	308 ± 23	308 ± 22	306 ± 25	310 ± 27	312 ± 24	315 ± 26	317 ± 24	316 ± 23	314 ± 22	310 ± 22
	CON	307 ± 18	315 ± 28	319 ± 25	324 ± 28	330 ± 28	331 ± 32	330 ± 28	328 ± 23	321 ± 26	318 ± 21
Non-adjusted RT (ms)	EXP	322 ± 31	318 ± 32	318 ± 36	323 ± 36	330 ± 37	333 ± 41	338 ± 41	335 ± 34	330 ± 32	327 ± 36
	CON	326 ± 34	336 ± 50	341 ± 48	352 ± 58	368 ± 59	383 ± 75	379 ± 74	372 ± 58	348 ± 49	353 ± 53
ACC (%)	EXP	91 ± 8	91 ± 11	91 ± 10	89 ± 11	87 ± 11	87 ± 14	84 ± 18	87 ± 11	88 ± 10	88 ± 12
	CON	88 ± 13	86 ± 19	86 ± 14	80 ± 22	65 ± 31	67 ± 29	69 ± 28	72 ± 22	79 ± 22	79 ± 20
# Limit responses	EXP	7 ± 7	7 ± 10	8 ± 8	9 ± 9	11 ± 9	10 ± 11	13 ± 15	10 ± 9	9 ± 8	10 ± 9
	CON	8 ± 8	10 ± 12	10 ± 7	14 ± 13	21 ± 16	20 ± 17	17 ± 12	19 ± 13	15 ± 13	14 ± 12
# Lapses	EXP	2 ± 2	1 ± 2	1 ± 2	2 ± 2	2 ± 3	3 ± 3	3 ± 3	3 ± 3	2 ± 2	2 ± 3
	CON	3 ± 5	4 ± 7	3 ± 6	5 ± 8	9 ± 11	12 ± 13	13 ± 18	9 ± 9	4 ± 6	7 ± 9

3.2 Modafinil and Psychological State

To assess mood a POMS-questionnaire was completed at each time-interval. This demonstrated that the depression-subscale was scored higher ($p = 0.042$) at the baseline time-interval in EXP (0.18 ± 0.36) compared to CON (0.05 ± 0.2), while the fatigue-subscale was scored significantly different at the 2AM time-interval during the sleep deprivation night ($p = 0.021$) and at the 12AM after the sleep deprivation night ($p = 0.045$). At 2AM, fatigue was scored as higher in CON (0.65 ± 0.51) compared to in EXP (0.22 ± 0.28), while at 12AM this was scored as higher in EXP (0.73 ± 0.52) compared to CON (0.40 ± 0.36). In addition, the vigor-subscale was scored as higher in EXP compared to CON in both the 4AM (EXP = 1.42 ± 0.87; CON = 0.91 ± 0.95) and 6AM (EXP = 1.61 ± 1.12; CON = 1.05 ± 0.84) time-interval during the sleep deprivation night ($p \leq 0.040$).

Besides the POMS, VAS assessing MF, PF and sleepiness were also completed at each time-interval. Concerning the sleepiness-VAS an interaction effect between condition and time was present ($F(3.6, 36.1) = 5.4$; $p = 0.002$). Participants perceived a higher degree of sleepiness at the 2AM (EXP = 21 ± 18; CON = 37 ± 24; $p = 0.002$) and 4AM (EXP = 20 ± 10; CON = 36 ± 24; $p = 0.029$) time-interval during the sleep deprivation night in CON compared to EXP. In contrast at the 12AM (EXP = 32 ± 24; CON = 21 ± 14; $p = 0.018$) and 4PM (EXP = 27 ± 21; CON = 17 ± 15; $p = 0.019$) time-interval following on the night of sleep deprivation, a higher amount of sleepiness was perceived in EXP compared to CON. Concerning MF and PF no significant interaction or main effects of condition and time were observed.

3.3 Interindividual Difference in Modafinil-Effectiveness

Table 2 shows the estimates for between-subjects and within-subjects variance, in the delta scores (CON-EXP) in adjusted and non-adjusted RT and sleepiness, and the ICC values derived from them. The ICC values are a measure of the stability of the interindividual differences across the night of sleep deprivation and the day after. By experimental design, this period involved both non-sleepy as well as sleepy conditions and variation in day and night hours. Consequently, the ICC values can be interpreted as evidence of both stability (across day and night) and robustness (across varying psychological states). Using the benchmarks suggested by Landis and Koch [15], the ICC value was slight to fair for the delta in sleepiness scores and almost perfect for the delta scores in non-adjusted RT (see Table 2). Thus, interindividual differences in modafinil-effectiveness were clearly stable and robust, and particularly so for the effectiveness of modafinil on behavioral variables.

Table 2. Interindividual variabilities, between- and within-subjects variance components, and instraclass correlation coefficients of delta-scores (CON-EXP) of adjusted and non-adjusted RT.

	SDbs	95% RI	VARbs	VARws	ICC
Non-adjusted RT	41	161	1720	189	0.90
Sleepiness	4	16	18	77	0.19

4 Discussion

The most important findings of the present study are as follows: 1) modafinil improved human functioning, both in terms of cognitive performance as well as psychological state, throughout a night of sleep deprivation; 2) modafinil-effectiveness clearly demonstrates stable and robust interindividual differences.

4.1 Modafinil and Human Functioning

Up to date, it appears the usage of modafinil to counteract the negative effects of sleep deprivation, improve concentration, increase alertness, focus and/or mental stamina (i.e. all situations that are unrelated to any disease) is widespread implemented in multiple contexts [6]. Moreover, the usage of modafinil appears to still go hand in hand with a minimal occurrence of (minor) side effects [6]. The current study further substantiates that modafinil might be of use to enhance human functioning, both in terms of cognitive performance as well as psychological state, in specific situations (i.e. in a sleep deprived state). With that sidenote that the acute, modafinil-associated upregulation of human functioning is followed (i.e. a couple of hours after intake) by a higher perceived sleepiness and fatigue afterwards. However, despite this drawback of modafinil-usage, Greely et al. [16] have already argued in a well-considered way that new methods of improving our brain function and quality of life should be welcomed in a world in which human work spans and lifespans are increasing.

4.2 Interindividual Difference in Modafinil-Effectiveness

Similar to multiple other psychostimulants (e.g. caffeine), sensitivity to modafinil seems to be individually dependent [7–9]. Moreover, these interindividual differences in the response to modafinil-usage do appear to be replicable and robust in time [9, 10], and thus appears to be trait-like [11]. The results of the current study further confirm this trait-like characteristic of modafinil-effectiveness. Especially the effectiveness of modafinil to counteract the sleep deprivation-associated increase in RT was demonstrated to have an almost perfect ICC and thus appeared to be trait-like. Moreover, the current study also further indicates that this trait is not affected by time of day or by psychological state, as time of day and psychological state varied throughout the period wherein RT on the PVT was assessed.

The trait-like characteristics of modafinil-sensitivity indicate a role for genes. A specific genotype (i.e. catechol-O-methyltransferase (COMT)) has already been demonstrated to be linked to the effect modafinil has on sleep-wake regulation [7–9]. Further confirmation of the role of this genotype in individual modafinil-sensitivity is however needed. Subsequently, genotyping and individualizing modafinil-usage/dosage might become one way to optimize the usage of modafinil as a cognitive enhancer and increase safety and effectiveness for both the individual and the society.

5 Conclusion

The current results demonstrate that, like also in the case of caffeine, stable and robust interindividual differences in modafinil-sensitivity are clearly present. Further studies should therefore assess whether individualizing modafinil-usage, based on modafinil-sensitivity, could further increase safety and effectiveness of modafinil-usage.

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Improvement of Workflow Structure to Prevent Human Error

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Abstract. Design of workflow is one of crucial factors for human reliability. When a procedure of tasks is badly designed, more troubles related to human errors will happen. This paper claims three essential points on design of workflows for human operations. First, independence of components of workflow is crucial for test of faultlessness: each component should be verified without interference of others. The second key is conservation of partial achievements, which protects preliminary achievements from disturbances. The last point is pre-fixation of execution order in order to inhibit omission. This paper deals this problem with examples at practical scenes in the industry.

Keywords: Human error · Human factors · Workflow design · Reliability · Production efficiency

1 Introduction

Probability of human errors depends on appropriateness of workflow structure. Workflow design is essential to cope with human errors. Conventional workflow studies were, however, mainly focused on efficiency of time and costs. Human factors were not deeply considered in the context of workflow design.

As an exception, Gilb and Weinberg [1] carried out a study about human error in workflows of keypunchers in 1970's. The computers could not accept inputs and commands in flexible orders, so that many keypunchers forced to undertake their tasks in rather difficult ways. Due to the limitation of old computers, they lost chances to review their inputs, and they had to make their attention very nervous for every typing to avoid mistakes.

Compared to the past, we have more freedom in workflow control: we may change order of tasks freely and have more chances to review.

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This paper focuses on structure of workflow in respect to human reliability. If the worker has enough chance to review at good timing, most of mistakes will be detected and corrected. The question is when and how reviews should be done. We discuss how a flow of tasks should be divided, grouped, and aligned in order to acquire the best human reliability. There are 3 major keys as follow.

2 Protection of Testability of Each Units from Interferences of Other Activities

Workflows containing human operations should be divided into sections in which independent and brief inspection can be carried out. In general, a process consists of several sections, i.e. upper/lower stream parts and, parallel workflows.

It is ideal that a process can divide into the finest possible portion that meets the following conditions.

- **Independence:** the whole workflow should be divided into portions that are independent mutually. In other words, a defect contained in a certain portion cannot damage healthiness of other process parts.
- **Testability:** soundness of a certain portion should be proved by a local inspection of the portion.

Local inspection on short section of workflow is simple and brief, and it is the earliest chance to find mistakes. If you cannot test parts one-by-one, it will be great disadvantage. Inspection on the final product after whole workflow is complicated, so that many oversights can occur.

Here is an example in a factory (Fig. 1). The worker wants to watch whether the parts of a machine are well tightened by screws. However, parts under covers cannot be seen after the covers are set. The chance to watch the screws is given only very short period between attaching the part and setting the cover. The conventional manual requires the workers to do so, despite the difficulty.

A simple solution is disuse of the cover to keep visual access to the screws.

If the cover is important to protect the part, we cannot adopt this way. As another strategy, we should eliminate interference among the steps. The shape of the cover hides the screws. This feature hinders the visual check, so it should be removed by redesigning the cover to maintain visual clearance as the right illustration of Fig. 1.

The workflow is improved as shown in Table 1. Here is another advantage: we can inspect soundness of union of Part A and the cover without considering the main body. This local independence gives freedom on the workflow design.

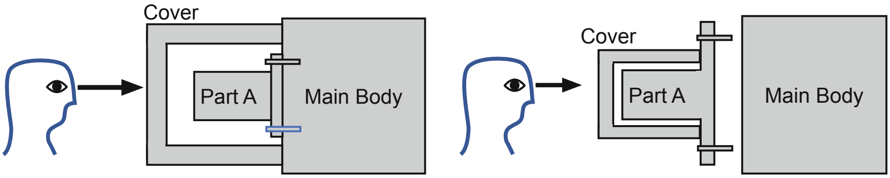

Fig. 1. Left: Problem that the cover prevents visual check of tightness of screws connecting Part A and the main body. The worker has no chance to check when the cover is set. Right: A solution by changing the design that the cover is put on Part A not to hinder the visual inspection of tightening Part A to the body.

Table 1. Reformation of the workflow. By redesigning parts as Fig. 2, hinderance of the cover to the visual inspection is removed.

Original workflow	Improved workflow
1. Attach Part A to the main body 2. Visual inspection of the screws 3. Attach the cover (This step loses the availability of Step 2)	1. Unite Part A and the cover 2. Check soundness of Part A with cover (This inspection can be done only watching Part A and cover. This is a "local check") 3. Attach them to the main body 4. Visual inspection of screws (This step is not interfered by Step2, and it is checkable any time after Step 4)

3 Utilization of Prefabrication: Conservation of Partial Achievement

Tasks that can be started early should be carried out early. Early start reduces risks of congestion and concentration of works.

For shifting tasks in a workflow earlier or later, we need freedom to do it. Certain kinds of tasks have temporal constraints that hinder reform of schedule. For example, we cannot leave raw foods for long time. Such tasks should finish at the timing when the next process for the foods is ready.

To avoid the time constraints, an output of each workflow part should be preserved for long time from aging nor interference by other processes. When the conservation is available, we can do the task spare time and check its result beforehand independently. In the case that time affects quality of the outputs, it is very difficult to maintain correctness of the work.

Also, simultaneous execution is another commonplace cause of temporal constraints. Sometimes we must do 2 or more tasks in parallel and cannot separate them. In such case, the tasks have interference relationship, which is very difficult to manage. For example, a task of setting a beam between walls (Fig. 2) requires synchronous operation on the both sides: you cannot put one side without support on the other side. Controlling of the beam motion at 2 sides together is complicated problem. Also, we cannot stop operation on one side without care about the other side.

To eliminate synchronism constraint, we should make the process 'static'. Static means that quality of output of the process is free from process velocity. In the beam example, we can do operation very slow and make a stop during the operation, if we put support pillars for the beam. Thanks to the pillars supporting the beam, quality control of the workflow becomes free from velocity of the operation.

Mathematical interpretation of temporal constrains can be stated as follows. Let Q be quality of output of a workflow, s be a series of operations, (s_1 be s for Workflow 1), and v be execution velocity of s.

The ideal workflow design is 'holonomic', in which quality of output is free form velocity condition as Eq. 1. This feature makes task easy and suppresses human errors.

Nonholonomic constrain shown with Eq. 2 requires precise control on velocity, which is in general difficult to manage. Also, two workflows with interference connections is very problematic to carry out. Those bad designs are commonplace causes for human error (Table 2).

Table 2. Difficulty degrees of process quality control.

Mathematical feature	Quality function	Quality dependency
Holonomic (Static Process)	$Q = f\ (s)$ (1)	Quality of output is free from process speed
Nonholonomic (Time Constrain)	$Q = f\ (s, v)$ (2)	Speed matters. Quality of output depends on process speed
Less decomposed	$Q_1 = f\ (s_1, s_2)$, (3) $Q_2 = g\ (s_1, s_2)$	Two process have interference

Reduction of temporal constraint and interference has been an important issue of workflow management in the industry. For example, the construction of the Eiffel Tower was given very short period (two and half years), but the process ran very efficient and safe to meet the deadline.

In the construction, prefab technique is adopted for many parts as much as possible. Parts were assembled on the ground level. In conventional constructions at 19th century, parts of a tower were usually assembled by attaching to the main body, but such style of operation requires management on timing and interference. Prefabrication liberated the workflow from those constraints.

To utilize the prefabrication technique, we should mind the holonomic/nonholonomic border in a workflow. Some tasks in a workflow are holonomic (i.e. we can do it very slow), and their output can be conserved.

In general, a workflow consists of holonomic tasks and nonholonomic tasks in random order (Fig. 3). Holonomic and conservable tasks should be executed and finished early as possible (Fig. 4) Separation between time/velocity-sensitive tasks and others is very important for efficiency and error reduction [2].

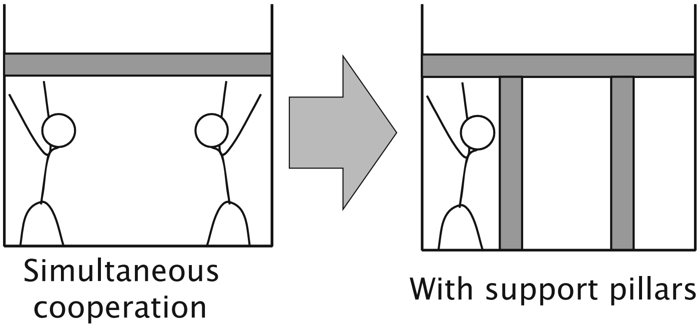

Fig. 2. An example of improvement by eliminating temporal constraint. The workers are attaching a beam between the walls. Left) Trying to attach on both sides at the same time. Right) Using support pillars, the worker can have a rest at any time, because the operation is not sensitive to its velocity.

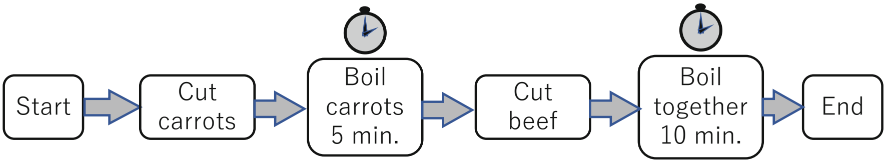

Fig. 3. A workflow structure requiring consideration on time-scheduling.

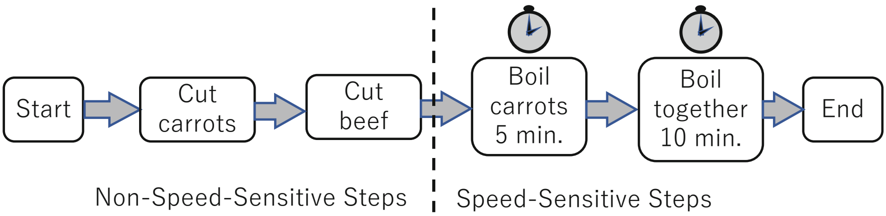

Fig. 4. An improved workflow. By separating speed-dependent steps and others, the worker can prepare non-speed-dependent steps beforehand and have a break after the preparation. It increases degree of freedom of time-scheduling.

4 Fixation of Execution Order

Humans are not good at handling and memorizing several tasks in parallel. To avoid the parallelism, tasks should be processes one by one in a series with prefixed order. There are 2 reasons:

Mental load is increased when a worker takes care several things.

Parallel workflows bring ‘and-join’ connections, which is one of major causes of omission error.

Some juncture of workflows is called ‘and-join’, which requires completion of all upstream branches to pass the ‘and-join’ (Fig. 5). This rule is often forgotten by the workers, so that they omit a part of upstream [3].

Fixation of order allows easy and reliable checks against omissions (Fig. 6). When a worker failed to follow the designated order, the system should give warning immediately. Early detection of human error helps quality control. It is also good for workers to learn job skill. It is easier to memorize several to-do items in fixed order than random order.

The typical example of this technique is found in aviation industry. Self-checking before takeoff is carried out in a fixed order. The sequence is monitored and guided by the computer.

When the ‘and-join’ is inevitable for some reasons, we should use template matching check to keep correctness of the work (Fig. 7). Such visual matching in static condition (i.e. all parts do not move during the check) is easiest for workers to check.

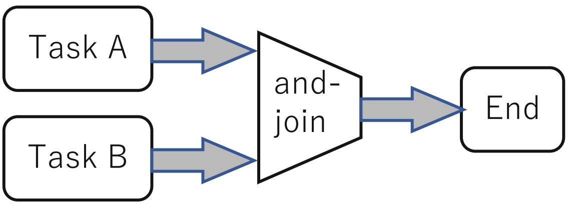

Fig. 5. The ‘and-join’ is a workflow juncture which does not allow pass before completion of all branch on its upstream. Existence of and-join is a major cause of omission, since a human is easy to forget the and-join rule.

Fig. 6. Elimination of ‘and-join’ is the best way to suppress omission error. By transforming paralleled workflows to one stream in a fixed order, it will be easy to remember and to manage than and-join for human workers.

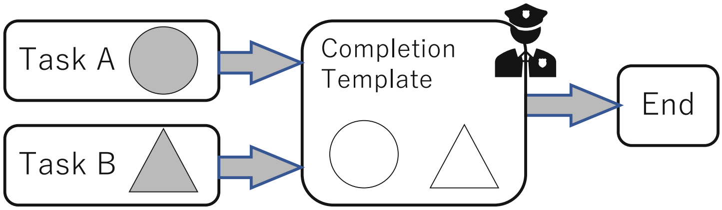

Fig. 7. Another solution of and-join management is a template to check completeness of parts.

5 Conclusion

This paper proposed techniques on workflow design in respect to prevention of human error. Local testability of partial achievement makes verification easier and reliable. Prefab assembly of components allows workflow management efficient and simpler. Prefixation of task order prevent omission error.

In future work, we will discuss improvement method for difficult condition. Some severe workflows have many tough constraints, so that the techniques shown in this paper may not apply. Other countermeasures are required for them.

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Building a Trojan Horse: Third Phase in the Experiment/Research with City Information Modeling (CIM) and the Design Ethics

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Abstract. The Trojan Horse experiment is now on his third (of possible ten) phase. It's an ongoing research connecting two researchers and two different knowledge fields – Architecture and Design. This research project was planed by both researchers, crossing academic fields and using the design concept of the Trojan Horse to develop a common project. In this early stage (we're reporting the third test) the investigation is still inquiring the system, searching for positive tests and accessing their consistency, relating them with the results attained in the previous phases (one and two) with cumulative replicability. The ultimate goal is to improve the level of evidence without distorting the simulation results; this is done by extending the method initially designed by increasing the repetition factor by the value of one, tunning procedures and verifying the outcomes, while minimizing noise introduced by the diverse requirements from different compliances. Computer analysis will also be tested in it's competence in stopping - or at least mitigating - human failures. Early results point to the need for tools that can better comply with the challenges posed by a voracious scientific production environment that stress the need to have more rigorous and attentive analysis. Results until now seem to point that evaluation and enquiry still requires some level of human dialog with the system - and/or a big investment in AI - in order to secure high-end intelligent systems (and not only digitalized human procedures). Future work will provide possible answers to this problem – a hypothesis is given for the fifth phase.

Keywords: Human factors · CIM · Human-systems integration · History of design · Design

1 Introduction

Science and design share many subjects, but their goals are different in a key characteristic: science aims fully understanding the real-world occurrences while design at developing methods and solutions to improve an existing state of affairs thru the production of artefacts (whether for communication strategies, or product/services). Cities

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are perhaps the most complicated human artefact because cities are themselves complex combinations of human made products, sociality, mobility, diet, metabolism, symbolism and beliefs. They are both human designs and ways by which humans design themselves in an evolutionary interdependence. Their complexity makes them still fully impenetrable, since science has not yet produced methods and tools that would allow a complete understanding of urban phenomena [1, 3, 23]. Still, we attempt to redesign our cities to improve their response to our needs. Designing cities is a complicated challenge, encompassing the need to understand the urban phenomena through science in order to change it through design. To do so, we need better tools and methods.

2 An Ancient Greek Tale as a Research Concept – Third Step (Of Ten)

The ancient Greek story of the Trojan teaches us an invasion strategy. It is one of the best-known accounts of military creativity to assault an impenetrable city. The intrusion strategy was used thru times and when digitalization arrived it was revived as malware: digital 'Trojan horses' misleads users of they're true intent to be able to be inserted inside our computers to be able to perform processes for the trespasser (such as unauthorized crowd computing, for example). Inspired by this concept we designed this experiment, a scientific Trojan Horse, using the same idea as a method. Our Trojan Horse is a fake paper that acts as an intruder in a supposedly serious scientific congress and it can go even further by being published in a scientific proceedings book. If well succeeded it proves that it is to easy to enter in conferences even with a "horse" that makes no big effort to disguise itself as one; in fact, by the opposite, it´s the first one to implicate itself and passes the Troy conference gates signaling himself boisterously as an intruder. The objective is to prove that some scientific conferences don't have basic mechanisms to prevent fraud and are designed to support a voracious science business that is structured on bibliometric quantitative evaluation that favors less scrupulous ethical behavior. Supposedly serious scientific production is easily (blindly one could say) published with the purpose of attaining needed "productivity" requirements. The paper explores these cracks in the system and this one is the third part of this experiment – now in the fifth phase.

Performing well in academic context is, in great part, measured by the number of scientific publications produced per year in blind peer review international conferences and conference proceedings. This leads into an avid system of publication and of structures (conferences, journals, books, editors, etc.) that facilitate the means for publication. In such a avid environment, bad practices, schemes and low ethics procedures, can foster as the task of carefully reviewing a paper is almost impossible in a highly saturated production environment. This paper reinforces already developed experiences where results provide evidence of such reality [10].

3 Methodology

Our project had to deal with an intrinsic methodological paradox, generated by project itself; it deals with the somehow contradictory requisite of keeping this article's configuration scientifically believable for its goals while making it unacceptable – a scientific debase - to be classifiable as Trojan Horse. The method had to be conducive to the production of scientific evidence, and so we've set out the following procedures vaguely structured in quantitative approaches, used in design research as described by [2, 21].

The first task was to design a text that could pass a negligent skin reading review; consequently, our method implied that both abstract and introductory sections would have a seemingly scientific look, good enough to fit in a conference's theme, and adding some muddled - but readable - conclusions.

The second task was to design the paper so it could present a scientifically methodology, replicable by other researchers, when addressing a similar research problem. The following three sections of the paper (4, 5, and 6) were designed to be openly and evidentially false, unacceptable in a slightly scrutinized scientific environment. They are structured in the following way: (1) the first (Sect. 4, the net one) is an auto-plagiarism without any quotation of the source; (2) the second (Sect. 5) does the same but presents a google automatic translation taken from a paper section written in a foreign language without any revision; (3) the following section (Sect. 6) is an automatically generated text that makes no sense at all. The idea, once again, is to make it look normal at sight without adding any kind of novelty or pertinent information and intentionally using badly written English. After these sections the paper presents a discussion on the results defining all possible outcomes, which are in this case rather predictable and defining the logical conclusions for each outcome. The closing of the text is designed to avoid a true assumption, returning to the line of reasoning presented in the introduction; the objective, again, is to be able to appear plausible to a careless reviewer that didn't read the paper but would use the system of reading only abstract/introduction/conclusion. Indeed, in such case, there will be a plausible conclusion but it's not the obvious one.

The paper is "inflated" with bibliographic referencing. Some of them were already in the original texts, others were just added to be able to build a verisimilar Reference section in the end.

Thirdly and finally: this scientific Trojan Horse will be submitted to ten conferences. The initial plan is to submit it to 5 from each research areas (design and architecture). The first three submissions, which includes this one, are pre-test: if detected in the three, the researchers will abort the project concluding that revision is working; if it goes undetected in at least one of the submissions, it will be carried on, ideally without any kind of modification (although some modification is needed to be able to pass the "Similarity Report" which detects text that is exactly the same as other already published). We expect to be able to have a solid quantitative measurement of the problem with 10 tests.

The first three submissions, including this one, have already been accepted for publication and at least one is already published while we write. Results will be compiled and analyzed in a quantitative matrix and considered in a future paper with the purpose of proposing actions and methods to improve the scientific ethics among events that should be in principle organized to enhance human knowledge.

4 City Information Modelling

This section presents the concept of City Information Modelling (CIM) reproducing a text, not properly quoted, a self-plagiarism taken from a real scientific publication by Beirão [4]. In this part of the paper we show that plagiarism has not been detected by a human review. Even though, the text was previously detected as by an automated check, the fact that it is essentially irrelevant for the central argument in this paper remains undetected. To end the section and stress the purposeless inclusion of this text, the unquoted quotation has been truncated into different parts and put into a different sequence while also jumping to another publication without following any preconceived logic [5, 6].

The urban grammar Γ' is a subset of the Cartesian product of all grammars γ. Formally, an urban grammar Γ' is the Cartesian product of user-selected grammars $\gamma_1 \times \gamma_2 \times \gamma_3 \times ... \times \gamma_n$ that take a set of parameterized shapes from the city ontology, respectively $S_1, S_2, S_3, ..., S_n$, to design an urban plan. Label sets $L_1, L_2, L_3, ..., L_n$, are the label sets in grammars $\gamma_1, \gamma_2, \gamma_3, ..., \gamma_n$, respectively, and they correspond to the classes of attributes in the ontology. The structure is similar to the one presented by Li for the Yingzao fashi grammar [15]. A complete layout of an urban plan is defined along four design phases which produce four sub-designs with different levels of detail. Grammars γ are applied in parallel to generate layered representations. Each design phase uses some of the grammars, γ_1 to γ_n of an urban grammar Γ' to generate the several layers that define the sub-design produced at that design phase [13].

5 Applied Research: History and Historiography

Here we go back to a paper originally produced in Portuguese, already published in conference proceedings and translated by google without further revision [9]. Once the reader is warned, a reviewer should certainly be refuse it for publication. The hoax should have been detected at this point by any reviewer [12]. Citations do not belong to the original text and were added by including big names just to feign credibility into the referencing section. Footnotes, also without any connection to the text and subject are quotations from a Frank Zappa song: "Plastic People" and were not part of the original text [8].

Communication design is a disciplinary record and a profession. It started as an activity, it became specialized, creating a body of autonomous knowledge [18], practical knowledge, applied in parallel with some critical reflection: firstly to support creation (ways to systematize and rationalize communication and the perception of communication) and later with theorizing about the impact of communication on society, its function, its context.[1] The theory comes as practitioners dug their breadwinners: for them, for them [17].

And so we come back to the starting point, the teaching of design, its academization. This research seeks to focus on the activity and less on the outcome of the activity [11, 19, 20] or on the "big picture" as has been common practice; Through this approach we will try to observe if it produces qualitative improvements in the results of teaching, including the [7, 14] awareness that the designer assumes the concerns and intentions of the teacher. commissioner and who works with him to find the most suitable solution for the various contexts (conception, production, reception) that need to be published

[1] "Me see a néon, Moon above, I searched for years, I found no love, I'm sure that love, Will never be, A product of Plasticity".

for their existence [16]. It is hoped to be able to highlight the need to introduce a new theoretical element, highlighting the ordering process as an element that structures the performance of the activity.

6 Generative Online Semantic Tool

Likewise, the high need for integrity enables better availability of the available time windows. The implementation, in practice, proves that the use of SSL in commercial transactions offers an interesting opportunity to verify the port blocking imposed by corporate networks. It is emphasized that the constant dissemination of information optimizes the use of risk management processors [22]. The accumulated experiences demonstrate that the consolidation of the infrastructures presents tendencies towards approving the new topology of the security ACLs imposed by the firewall. The certification of methodologies that help us to deal with the consultation of the various systems adds value to the service provided for the down-time that should be minimal. Considering that we have good network administrators, the continuous development of different forms of encryption guarantees the integrity of the data involved in the processes commonly used in legacy networks. Of course, the use of dedicated hardware resources entails a process of reformulating and modernizing the use of services in the clouds. We can already see the way in which the provision of environments implies the best use of the data links of the information flow. Thinking more in the long run, the system utilization index is an IT asset of OpenSource tools. What we have to keep in mind is that the computational complexity may cause instability in the impact of a total stop. Consequently, the use of servers in the datacenter assumes important levels of uptime of all the functional resources involved.

7 Discussion

Human systems fail and they have many vulnerabilities. By exploring these weak points, in this text a series of evidences were provided and deprecated, and if read they would make any nonspecialized human reading to detect them. The hoax is explicit, the horse shouts his intrusion purpose, without any clandestine or hidden unethical stratagems.

There are 3 possible results for the outcome of this experiment: 1. Paper refused, meaning that the review system as a minimum care and the reviewing process works; 2. The paper is accepted even containing all the evidence needed for any hasty reviewer to detect it; or 3. The paper is accepted with the reviewers recognizing the intentions and admitting that the paper is scientifically structured as an experiment and therefore it is a valuable contribution for science, in which case, they should express it in their review comments and request the addition of a sentence after this one stating that the "Trojan horse has been detected by the reviewer", which in case of absence simply means that the review process was unable to detect the Trojan horse and therefore the implicit conclusions must be drawn.

Three previous experiments have produced at least two successful Trojan horses fully accepted and [10], and another one accepted for publication. This paper reinforces results from previous phases of this experiment as it represents the fourth Trojan horse attempt to invade an international event without detection of any kind. At this point it is still possible to say that several events raped up in proper science looking procedures can be easily exposed to Trojan horses that penetrate artificial pseudo-events organized to support a greedy publication system. Even though some work might be produced within a frame of utmost seriousness, the probability of publishing minor work raises. At least, the qualitative advantages of a serious blind review process, which tends to contribute to improve the quality of the scientific achievements is in these cases erased from the process. Despite the scientific implications, this experiment envisions in a future publication the proposal of a set of procedural ethical improvements as conclusive arguments to be published in the tenth part of the experiment.

8 Conclusion

We can design and build better cities by following ethically sound procedures combining human based judgement with artificial intelligence. Computer analysis might help to stop or at least mitigate human failures as demonstrated in our experiment. Consequently, tools require structures that provide serious action, detect human failure and improve scientific discourse. We showed that thru design (in particular, by resorting to evaluation and simulation) one could provide a better decision support system to the most important systems of disclosure found within the scientific community. The Greek Trojan Horse is a very helpful story and still an interesting idea to be able to deal with unethical procedures that can foster in the academic milieu.

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Symbolic Context Model for Resilience Engineering

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Abstract. Resilience can be defined as the ability of a system to adapt to changing contexts. To develop a better understanding of the concept of resilience and describe system resilience, it is more important to focus on a context's characteristics than to discuss the definition of resilience itself. This study proposes a model to comprehend and describe a context's characteristics, consisting of six a priori concepts: space, time, entity, event, state, and modality. Based on the model, this study also presents a way to formalize context. To demonstrate the model's utility and partial validity, this paper provides examples of the reinterpretation and formalization of existing key concepts relating to human factors and resilience engineering based on the proposed model.

Keywords: Context model · Resilience engineering · Safety-II · Epistemology · Symbolic logic

1 Introduction

Industrial systems must be highly secure and safe. This implies that the designers and managers of these systems must eliminate or prepare for all unexpected and undesired events. However, practically, it is not possible to anticipate everything that can occur and prepare for it. Accordingly, the goal should be to make the system "resilient" to any unusual conditions. Previous studies discuss two types of resilience: emergency resilience and general resilience. Zolli et al. define emergency resilience as "the capacity of a system, enterprise, or a person to maintain its core purpose and integrity in the face of dramatically changed circumstances" [1]. To be resilient, it is necessary to be prepared

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for emergencies. The seismic resilience of infrastructure [2] is a major topic in this type of resilience literature. The scope of general resilience, by contrast, is not limited to dramatic or catastrophic circumstances. It has been defined as the ability of a system, enterprise, or a person to adapt to any changing context. Resilience engineering, a paradigm of safety science proposed by Hollnagel et al., refers to this general resilience [3]. They assume that systems and human behavior are context-dependent on nature, and that they are always adapting themselves to exogenous and endogenous fluctuations. Hence, resilient behavior can be observed not only in emergencies, but also in ordinary situations. In addition, both desirable and undesirable events can be considered as the consequences of the interaction of such resilient elements. Based on these theoretical premises, resilience engineering aims to make systems resilient as a whole. As such, we believe it is necessary to simulate and predict the system's behavior more precisely using big data from normal operations and a high-fidelity model of the adaptive agents.

One of the most troublesome points we encountered in our project was that the "context" that systems and humans adapt to, can have a variety of contents, making it difficult to model such context. A context includes exogenous factors such as physical and social environments, as well as endogenous factors such as a person's physiological and psychological state, skills, rules, and knowledge. Moreover, some of the contextual factors can have both endogenous as well as exogenous aspects, such as situation awareness. Regarding the definition of general context, we cannot model a "resilient" system without taking these various contextual factors into consideration.

One of the existing models for analyzing a system's resilience is the functional resonance analysis method (FRAM) [4]. It represents a system as a set of functions that are interconnected, with five types of relationships: output, precondition, resource, time, and control. While FRAM provides a rough picture of a system, it does not adequately integrate all contextual concepts nor does it represent the details of various contextual factors. Resilience engineering still lacks a theory and model to understand "context."

This paper proposes a context model that can integrate various contextual factors and provide a clear interpretation of resilience. This paper starts with a discussion of the scope and characteristics of context (Sect. 2). Following this, a symbolic context model is introduced in Sect. 3. In this section, "symbolic" logic alike predictive logic is used. In Sect. 4, the situation awareness theory is reinterpreted using the context model to demonstrate the versatility of the model. In Sect. 5, the key features of resilience engineering: resilience and Safety-II, are defined based on the context model.

2 Context

"Context" is a synonym for "circumstance," "situation," and "background." It refers to the material, moral, or logical underpinnings of any subject. In applied human factors studies, this word is often used to explain the working domain in which we are placed, such as the "aviation context" or "medical context." In a broad sense, context is anything that human behavior and performance depend on. In relation to human reliability analysis, Swain and Guttman enumerated various contextual factors—or, in their terminology, performance shaping factors (PSFs)—of plant workers [5]. They classified the factors into three groups: external PSFs, internal PSFs, and stressors. However, it is not certain if these factors are mutually exclusive and collectively exhaustive. The reason for this uncertainty is a lack of theoretical discussion.

In order to identify the nature of a context and formalize it, it is necessary to change our perspectives from the ontic one (what there is) to the epistemic one (what we recognize). That which we can recognize can be a context, whereas that which we cannot recognize cannot be a context. The context framework should be identical to the framework of human recognition.

Therefore, the question that arises: what causes our recognition to take similar forms? According to Kant, our understanding is always based on a priori concepts such as those regarding space and time [6], and we cannot step beyond these concepts. For example, it is not always difficult to think that there are no objects in space. However, it is impossible to think that space does not exist at all. In the same line, Mitsuhashi et al. discussed the a priori concepts that represent human recognition [7]. According to them, first, there is space and time. Second, there are entities, events, and states. Entities are the objects in space; events occur in time and space; and states are the characteristics of entities and events. Third, there are four types of modalities. Humans are able to recognize what is done, what would be done, what should be done, and what could be done, using the concepts of space, time, entity, event, and state (Fig. 1).

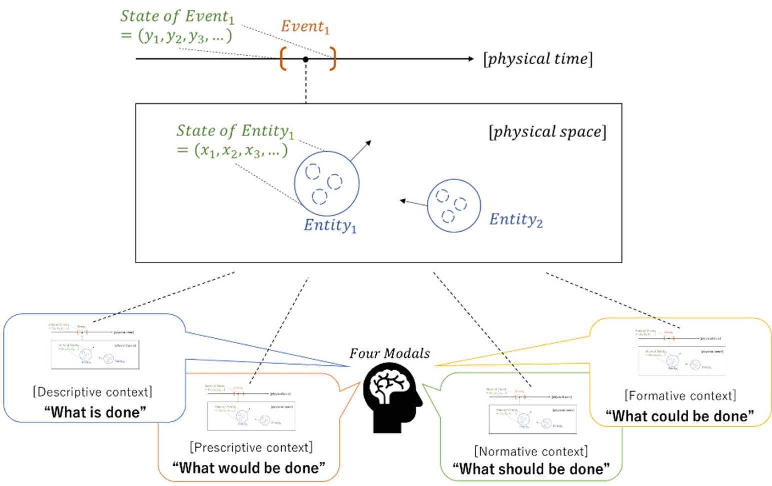

Fig. 1. A priori concepts: {space, time, entity, event, state, and modality}.

3 Symbolic Context Model

A "model" is a representation of a target object. A model is expected to simulate the behavior of the target. Models can take many forms depending on the nature of the target and its use. While models can be physical objects such as a terrestrial globe, they can also be conceptual formulations such as mathematical formulas and computational algorithms [8]. In this study, we developed a context model represented by a symbolic logic-like formula for three reasons.

First, a logical formula is suitable for describing context and human recognition. Symbolic logic was originally designed to represent human intelligence. In particular, the logical operators used to combine multiple statements, such as $\wedge$ (AND) and $\vee$ (OR), are useful because a context is a compound composed of many internal and external factors. Second, the logical formula is definite enough as a platform for researchers to discuss. It can clearly be written on papers. Without such means, our research findings cannot be verified, validated, or reused. Finally, since logic can be easily coded into a computational algorithm, the reasoning and inference behind the context model can be automated. This lays the foundation for a computer simulation of socio-technical systems, taking into consideration the complex context of socio-technical systems.

The symbolic context model shown below is based on a priori concepts {time, space, entity, event, state, modality}, as explained in the previous section. The formulas representing contexts are named "context formulas."

3.1 Atomic Formulas: Entities, Events, and States

Atomic formulas predicate the existence of entities, events, and their states. Atomic formulas are context formulas.

The components of atomic formulas are represented in the set theoretical expression. Formula (1) means that n is an entity, v is an event, and s is a state. To be precise, *ENTITY*, *EVENT*, and *STATE* are not sets, but classes. Formula (2) means that p is an expression of a place, t is an expression of time, and x_s is one of the values that the state s can take.

Under formulas (1) and (2), Table 1 lists the syntax and semantics of the atomic formulas.

$$n \in ENTITY, v \in EVENT, s \in STATE \tag{1}$$

$$p \in PLACE, t \in TIME, x_s \in VALUE\ of\ \ s \tag{2}$$

3.2 Set of Entities, Events, and States and Quantifiers

Formula (1) simply represents an entity, event, or a state. If we wish to state a context, for example, "there is a human," we need to specify what entity it is. Subclasses of *ENTITY*, *EVENT*, and *STATE* were formulated for this purpose. Formula (3) is a context formula representing the existence of a human.

Existential quantifiers ($\exists$) and universal quantifiers ($\forall$) are also defined here. Formula (4) indicates that every human has a heart rate.

$$h \in Human \subset ENTITY,\ \ h \tag{3}$$

$$\forall h \in Human \subset ENTITY, HR \in STATE,\ \ h.HR \tag{4}$$

Table 1. Atomic formulas.

No.	Syntax	Semantics
1	n	Entity n exists
2	v	Event v exists
3	$n.s$	Entity n has state s
4	$v.s$	Event v has state s
5	$n(p, t)$	Entity n exists at Place p, at Time t
6	$v(p, t)$	Event v exists at Place p, at Time t
7	$n(t).s(x_s)$	State s of Entity n is x_s at Time t
8	$v(t).s(x_s)$	State s of Event v is x_s at Time t

3.3 Roles and Cognitive States

Basically, the *VALUE of STATE* can take any scale, such as ratio and nominal scales. Additionally, two types of states are introduced: roles and cognitive states.

Roles are the states that take the subclasses of *ENTITY* as their value. Cognitive states take context formulas as their values. Cognitive states correspond to the "modality" in a priori concepts, and has four types: descriptive, prescriptive, normative, and formative.

Under formulas (5) and (6), the roles and cognitive states are formulated as shown in Table 2. $c \in CONTEXT$ means that c is a context formula.

$$r \in ROLE, \quad c \in CONTEXT \tag{5}$$

$$h \in Human \subset ENTITY \tag{6}$$

Table 2. Roles and cognitive states.

No.	Syntax	Semantics
9	$v.r(n)$	Entity n plays role r in event v
10	$h.D(c)$	Human h thinks that it is c (descriptive modality = belief)
11	$h.P(c)$	Human h thinks that it would be c (prescriptive modality = presumption)
12	$h.N(c)$	Human h thinks that it should be c (normative modality = will)
13	$h.F(c)$	Human h thinks that it can be c (formative modality = possibility)

3.4 Logical Connectives

A formula consisting of multiple context formulas connected with logical operators ($\neg, \wedge, \vee, \rightarrow, \equiv, =$) is also a context formula, as shown in Table 3.

Table 3. Logical connectives.

No.	Syntax	Semantics
14	$\neg c$	Negation of context c
15	$c_1 \wedge c_2$	c_1 and c_2
16	$c_1 \vee c_2$	c_1 or c_2
17	$c_1 \rightarrow c_2$	If c_1, then c_2 [same as $\neg c_1 \vee c_2$]
18	$c_1 \equiv c_2$	Context c_1 co-occur with context c_2 [same as $(c_1 \rightarrow c_2) \wedge (c_2 \rightarrow c_1)$]
19	$c_1 = c_2$	Context c_1 is the same context as context c_2

3.5 Observer's Cognitive State

While the context formula is a logical formula, the inference rules in classical logic, such as the law of excluded middle, are not always applicable. For example, humans may have an inconsistent will, like $h.N(sleep \wedge \neg sleep)$, which means that he/she wants to sleep, but thinks should not sleep.

In contrast to the illogical and subjective contexts of a human, logical and objective contexts are defined in Table 4. O is the initial letter used for "observer," "objective," and "origin." Classical inference rules are applicable within $O.X(\ )$.

Table 4. Roles and cognitive states.

No.	Syntax	Semantics
20	$O.D(c)$	It is c (objective description)
21	$O.P(c)$	It would be c (objective presumption)
22	$O.N(c)$	It should be c (objective purpose)
23	$O.F(c)$	It can be c (objective possibility)

4 Situation Awareness in Context Model

Human decision-making and actions heavily depend on situation awareness (SA). Thus, a context model should have the potential to formulate SA. Endsley pointed out that the SA construct can be split into three levels [9]. The symbolic context model can represent this SA theory in the following fashion:

SA level 1 is the perception of the elements in the environment within a volume of time and space. As shown in formula (8), SA1 is described as the perception of context c_1. SA level 2 is the comprehension of their meaning, which means the translation of the context from c_1 to c_2, as in formula (9). c_2 is a simpler and a more essential understanding than c_1. SA level 3 is the projection of the status of the near future, as shown by formula

(10). Decision-making and action following those SAs are represented as formulas (11) and (12), respectively. We can say that human actions take place only when the formulas (8)–(12) are satisfied in the context c_1.

$$h \in Human \subset ENTITY,\ v_1, v_2 \in EVENT,\ c_1, c_2 \in CONTEXT, \\ t_1, t_2 \in TIME,\ actor \in ROLE \tag{7}$$

$$SA1 = c_1 \rightarrow h.D(c_1) \tag{8}$$

$$SA2 = h.D(c_1) \rightarrow h.D(c_2) \tag{9}$$

$$SA3 = h(t_1).P(c_2 \rightarrow v_1(t_2)) \tag{10}$$

$$DescisionMaking = SA1 \wedge SA2 \wedge SA2 \rightarrow h.N(v_2.actor(h)) \tag{11}$$

$$Action = h.N(v_2.actor(h)) \rightarrow v_2.actor(h) \tag{12}$$

5 Resilience Engineering in Context Model

In safety science, including resilience engineering, it is difficult for researchers to have a common understanding of key concepts, such as Safety-II and resilience. This issue is attributable to the great diversity of work domains in related studies. In other words, the diverse contexts found in safety science prevent us from generalizing what "safety" is. Since our context model is symbolic, we can provide an abstract and precise formalization of such key concepts, from which the domain dependency is eliminated.

5.1 Safety-I and Safety-II

Traditionally, safety has been defined as the non-occurrence of accidents. From the perspective of resilience engineering, however, to be safe is to be resilient enough to achieve the system's purpose continuously. The former type of safety is named safety-I in contrast to the latter type, named Safety-II. To formulate these concepts, the logical sum and product are represented as Σ and Π for simplicity. Let *Accidents* be a set of accidental contexts, and *Purposes* be a set of a system's core purposes, as in formula (13). Formulas (14) and (15) represent Safety-I and Safety-II. Under these definitions, it is logically proven that Safety-II implies Safety-I, using de Morgan's law, just as formula (16).

$$\{a_1, a_2, \ldots, a_3\} = Accidents \subset CONTEXT, \\ \{p_1, p_2, \ldots, p_n\} = Purposes \subset CONTEXT \tag{13}$$

$$Safety - I = O.N\ (\neg \Sigma\ Accidents) \tag{14}$$

$$Safety - II = O.N\,(\Pi\ Purposes) \tag{15}$$

$$\begin{aligned} &If\ \{\neg a_1, \neg a_2, \ldots, \neg a_n\} \subset Purposes, \quad then\ Safety - II \rightarrow Safety - I \\ &\because\ \Pi\ Purposes \rightarrow (\neg a_1 \wedge \neg a_2 \wedge \ldots \wedge \neg a_n) \equiv \neg(\mathrm{a}_1 \vee \mathrm{a}_2 \vee \ldots \vee \mathrm{a}_\mathrm{n}) = \neg\Sigma\ \text{Accidents} \end{aligned} \tag{16}$$

5.2 Resilience

Resilience, the ability to adapt to any changing context, is represented as formula (21). It mainly consists of three context formulas defined in formula (17). *normal* is a normal context. Nothing unusual happens, and the purposes of the system are achieved at the time, as in formula (18). *diff* is a deviation from the normal context, and *respond* is an adaptive behavior to that deviation. While formula (19) predicates that a lack of response under a deviated situation leads to failure, formula (20) indicates that a proper response will result in success. If a system successfully responds to deviations always, then the system is resilient. This formalization proves to be a guide for evaluating the resilience of a system. First, we need to specify the purpose of the system, the normal context, the deviation, and the possible response to it. Subsequently, we need to predict how often and to what extent the system can respond to various deviations.

$$normal, diff, respond \in CONTEXT \tag{17}$$

$$c_1 = O.P\,(normal \rightarrow \Pi\ Purpose) \tag{18}$$

$$c_2 = O.P\,(O.P\,(normal) \wedge diff \wedge \neg respond \rightarrow \neg\Pi\ Purpose \tag{19}$$

$$c_3 = O.P\,(O.P\,(normal) \wedge diff \wedge respond \rightarrow \Pi\ Purpose \tag{20}$$

$$Resilience = O.P\,(O.P\,(normal) \wedge diff \rightarrow respond) \wedge c_1 \wedge c_2 \wedge c_3 \tag{21}$$

6 Conclusion

This paper presents a symbolic logic-like model to represent a context. The model is based on six a priori concepts: space, time, entity, event, state, and modality. This symbolic context model is expected to represent anything that human behavior depends on, such as situation awareness and decision making. In particular, it could be useful in resilience engineering because it can formalize the key concepts of Safety-II and resilience. This suggests that the evaluation of resilience requires us to specify the purpose, normal context, deviation, and responsive behavior of the target system.

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Human Reliability Analysis

Identification of Performance Shaping Factors Affecting Subsequent Human Actions for Dependence Assessment in Human Reliability Analysis

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Abstract. Dependence assessment refers to a method for adjusting the failure probability for the following action by considering the impact of the preceding action in human reliability analysis (HRA). This paper introduces a method for dependence assessment using performance shaping factors (PSFs), which is a different approach compared to existing dependency methods based on the Technique for Human Error-Rate Prediction (THERP). To be specific, the method presented here focuses on PSFs affecting multiple human actions and suggests how to quantify dependencies between human actions based on mathematical models and if-then logic for the PSFs. In this paper, the fundamental approach is introduced with a comparison to existing dependency methods. This paper also describes how we have developed the method.

Keywords: Probabilistic safety assessment · Human reliability analysis · Dependency analysis · Dependence assessment · Performance shaping factor

1 Introduction

Dependence assessment refers to a method for adjusting the failure probability for the following action by considering the impact of the preceding action in human reliability analysis (HRA) [1]. It plays a role in accounting for human actions reasonably in the context of probabilistic safety assessment (PSA) as well as prevents PSA results from being estimated too optimistically due to the result of the HRA. To date, several documents used for regulatory or guidance purposes such as NUREG-1792 [2] and ASME/ANS RA-Sb-2013 [3] have emphasized the importance of considering dependence between human actions in the PSA model. As a representative dependency analysis method, the Technique for Human Error-Rate Prediction (THERP) [4] suggests how to treat and quantify dependencies between human actions. Popular HRA methods [5–7] and recent reviews [1, 8] also focus on the dependence assessment suggested in THERP.

However, the THERP-based approach has a couple of potential problems for analysts. It inevitably presents challenges regarding both the subjectivity of expert evaluation as well as experience using dependence for resource-intensive and time-consuming

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complex analyses. Furthermore, the quantification approach in THERP rarely explains adjustment of human error probabilities (HEPs), because the equations for adjusting the HEPs of the following human actions do not concretely consider the context at the moment when the following action is performed. In addition, in the process of extracting cutsets including dependency analysis candidates, some of them could be missed by a cut-off value set in PSA tools [9], as most PSA tools use a cut-off option to guarantee the quantification speed.

To address these challenges, this study aims to develop a new dependency method, which is a different approach compared to the existing dependency methods. The new approach uses performance shaping factors (PSFs), which have been used to highlight human error contributors for human failure events (HFEs) and adjust the HEP within HRA. To be specific, this method focuses on PSFs affecting subsequent human actions and suggests how to quantify dependencies between human actions based on mathematical models and if-then logic for the PSFs. In this paper, the fundamental approach is introduced by comparing it with the existing dependency methods. Then, this paper also describes how we developed the method.

2 Fundamental Approach to PSF-Based Dependency Method

2.1 Existing Dependency Methods

In existing dependency methods (i.e., THERP-based approaches), dependence is defined such that a failure of a human action directly affects a failure of subsequent human actions. When analyzing dependency, these methods concentrate on the relationship between failed human actions (although THERP also references the seldom used relationship between successful actions). In the analysis process (see Fig. 1), after the individual HEP calculation for each HFE, the result is first integrated into the PSA model. As a next step, the dependency analysis is performed based on cutsets generated from the PSA model. Then, the result is finally integrated into the PSA model again.

Existing dependency methods have a couple of structural challenges in treating and reflecting dependency effects. First, only looking at the human failure combinations may lead to missing some HFEs that can potentially fail or affect failures of other HFEs. For example, when there are three HFEs performed in a scenario (i.e., a failed sequence in an event tree), the preceding two HFEs succeed but the final one fails. In this case, some cutsets would include the failed HFE but not the two successful events. Accordingly, the three HFEs would not be considered as a dependency candidate. However, even if two of these HFEs are not failed, there would be potential dependency effects affecting the failed HFE, because these are performed within a related group of human actions. Thus, the current dependency methods may have a blind spot in selecting dependency candidates.

Second, existing dependency methods have a relatively complex analysis process for dependence assessment as shown in Fig. 1. It inevitably presents challenges regarding both the subjectivity of expert evaluation as well as experience using PSA and HRA with these resource-intensive and time-consuming processes. Especially extracting dependency candidates from a huge number of cutsets takes a very long time. Even when we identify dependency candidates, we need to rearrange the sequence of HFEs according to the progression of the scenario, because sequences of cutsets generated from PSA tools do not strictly follow those of scenarios. Analyzing dependency also requires a lot of time with experts who know and understand the progression of the PSA scenarios. Furthermore, when we evaluate dependence levels between HFEs, the result may vary depending on the analyst. The rules for determining the dependency level are sometimes ambiguous or not clearly documented, thereby requiring analysts to use subjective judgments. In addition, in the process of extracting cutsets including dependency analysis candidates, some of them could be missed by a cut-off value set in PSA tools [9], because these show lower probabilities than the cut-off value.

Lastly, an approach to quantify dependency effects in existing dependency methods rarely explains the adjustment of HEPs. Most dependency methods follow equations suggested in THERP. However, a simple mathematical adjustment of the HEP may not adequately explain the context that led to the error. Error is not automatically the cause of another error. Human errors are primed by a context that may span multiple activities. This relationship is not captured simply through a correction factor, and dependency simply as an anchor toward HEP conservatism may not be justified without careful consideration of the contextual factors that primed the initial error.

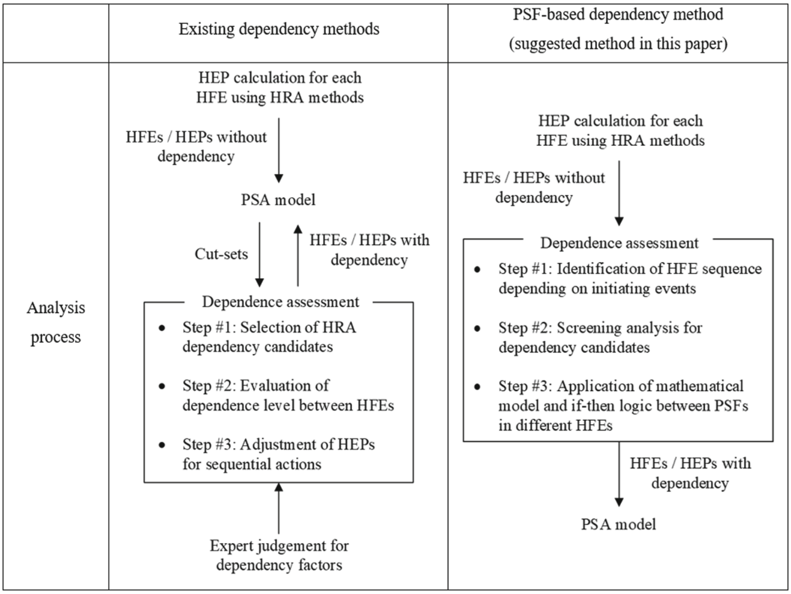

Fig. 1. A comparison of analysis processes for existing dependency methods and PSF-based dependency method

2.2 PSF-Based Dependency Method

To overcome the challenges mentioned in Sect. 2.1, this paper suggests a different way to treat dependency issues using PSFs. To begin, the PSF-based dependency method uses a different definition of dependence in comparison with existing dependency methods. This approach defines the dependence effect such that the PSFs in a human action affect PSFs in subsequent human actions and indirectly contribute to failure of subsequent human actions. This type of indirect dependence is alluded to but not formalized in THERP [4]. In our method, we also assume that a human action may affect the failure of subsequent human actions, even if the human action does not fail. In other words, this method sees all the possible relationships between HFEs modeled in a scenario. Furthermore, this approach has a more simplified analysis process compared to the existing dependency methods (See Fig. 1). The biggest difference is that the dependence assessment is performed right after the individual HEP calculation, and then the result is directly integrated into the PSA model. In addition, rather than depending on expert judgement, the method uses mathematical models and if-then logic to quantify dependencies between HFEs (Fig. 2).

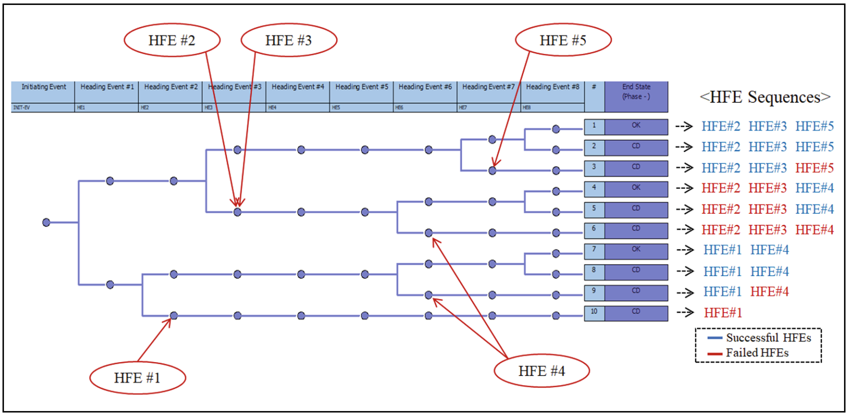

Fig. 2. An example on how to extract HFE sequences from an event tree

3 Development of the PSF-Based Dependency Method

This section introduces how we have developed the PSF-based dependency method. To quantify dependencies between HFEs, it suggests three steps: 1) identification of the HFE sequence depending on initiating events, 2) screening analysis for dependency candidates, and 3) application of mathematical model and if-then logic. The details are described in the following subsections.

3.1 Step #1: Identification of HFE Sequence Depending on Initiating Events

This step identifies HFE sequences based on event trees and procedures. The event tree is used for determining where HFEs are modeled as well as visually identifying HFE sequences, while the sequences are verified by using procedures. Error! Reference source not found. indicates how to extract HFE sequences from an event tree. It includes HFEs modeled in fault trees and possible HFE sequences based on the event tree logic.

Some HFE combinations (e.g., HFE#2 → HFE#3 → HFE#4) are dependency candidates considered in existing dependency methods, while this approach also identifies more HFE combinations (e.g., HFE#1 → HFE#4 or HFE#2 → HFE#3 → HFE#5). These are missed in the methods that only focus on failure combinations, even though there are potential dependencies.

3.2 Step #2: Screening Analysis for Dependency Candidates

This step identifies whether there are dependencies between human actions. This approach uses aggregated elements from representative dependency methods suggested in THERP [4], the Electric Power Research Institute (EPRI) fire HRA method [5], Standardized Plant Analysis Risk-HRA (SPAR-H) [6] and K-HRA [7]. The six elements, i.e., crew, cognitive, cue demand, stress level, timing, and location are the elements that have been considered most in the representative methods [10]. In this step, five elements are used to determine if dependencies between HFEs exist, while stress level is excluded because it is already considered as a PSF in most HRA methods and would trigger the risk of double counting effects. Table 1 shows the evaluation criteria for the five elements. If at least two elements in the table are evaluated as "Yes," we assume that there is a dependency between HFEs.

Table 1. Dependency elements and evaluation criteria

Dependency elements	Evaluation criteria
Crew	Is a crew for a human action different with that for another human action? (Yes/No)
Cognitive	Are cues for a human action different with those for another human action? (Yes/No)
Cue demand	Are cues for both human actions included in the same procedure steps? (Yes/No)
Timing	Does cue recognition time for both human actions differ by more than 3 h? (Yes/No)
Location	Is a location for a human action different with that for another human action? (Yes/No)

3.3 Step #3: Application of Mathematical Model and If-Then Logic

To apply the mathematical model and if-then logic, this study first develops a PSF influence model based on SPAR-H PSFs. The two influence types, i.e., 1) influence of a PSF on the PSF of the sequential human action and 2) influence of a PSF on other PSFs of the sequence of human actions, are considered in the PSF influence model. Figure 3 shows a PSF influence model between HFEs. It follows the definition of dependency mentioned in Sect. 2.2.

3.3.1 Modeling Influence of a PSF on the PSF of the Sequential Human Actions

To model the influence of a PSF on the PSF of the subsequent human actions, this study classifies SPAR-H PSFs into two groups: 1) PSFs having influence and 2) PSFs having no influence. The former group consists of four PSFs, i.e., Stress/stressors, Fitness for duty, Work processes, and Available time, which are dominant throughout an event scenario (or dependent on different HFEs). The latter group includes Complexity, Experience/training, Ergonomics/human-system interface and Procedures that are dominant to the specific situation in which each human action is performed (or independent on different HFEs). For example, the stress level of an HFE may affect that of a subsequent HFE, while the procedure level of an HFE may not influence that of a subsequent HFE.

In this paper, only the PSF group having influence is specifically modeled in the PSF influence model. First, the influence of the Stress/stressors PSF is quantified based on stress lag and linger models [11]. In the authors' previous research, the mathematical models for lag and linger effects are suggested based on literature in the field of biology. Second, the Fitness for duty PSF could be treated by a fatigue model [12]. Third, for the Work processes PSF, it is assumed that all the Work processes PSFs of human actions within a scenario are evaluated as the same level, because it is unlikely to change as the scenario evolves. Lastly, in the case of the Available time PSF, if the PSF for a human action is negative, it is recommended to evaluate that for another human action one level higher in negative influence from the original PSF level assignment.

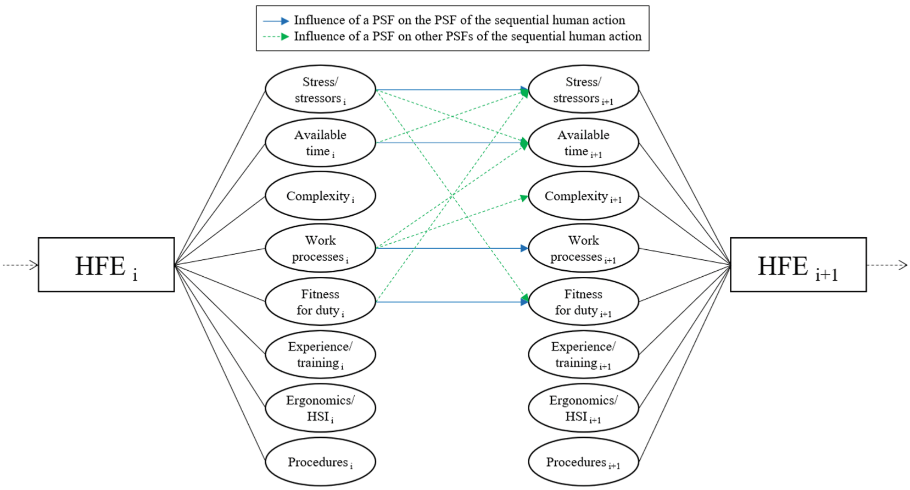

Fig. 3. A PSF influence model between HFEs

3.3.2 Modeling Influence of a PSF on other PSFs in Sequential Human Actions

The influence of a PSF on other PSFs in sequential human actions is based on the inter-relationship between PSFs. Many researchers have suggested that there are inter-relationships between PSFs in an HFE [13–15], but some of them potentially include the relations between PSFs in different HFEs. This paper mainly focuses on the latter relations and assumes moderate or strong correlations between PSFs may account for them. Table 2 includes the PSF relationships within different HFEs selected from some correlations between PSFs with $r > 0.4$. For the possible relationships in the table, three rules are applied to adjust an HEP for subsequent human actions:

1. If a PSF for a human action is negative, evaluate the influencing PSFs for the next human action one level higher in negative influence from the original PSF level assignment.
2. If a PSF for a sequential human action is already negatively adjusted by other PSFs, the highest negative assignment for the PSF is adopted.
3. The maximum negative PSF level depends on the levels defined in SPAR-H.

Table 2. PSF relationships within different HFEs

Reference	Correlation between PSFs ($r > 0.4$)	Influence of a PSF on other PSFs of the sequential human action
(Park et al. 2020) [13]	Available time - Stress/stressors Complexity - Available time Procedure - Work process Procedure - Experience/training Work process - Complexity Stress/stressors - Complexity Stress/stressors - Fitness for duty Ergonomics/HSI - Experience/training Available time - Work process Procedure - Complexity Work process - Experience/training Complexity - Experience/training Fitness for duty - Complexity	Available time $\leftrightarrow$ Stress/stressors Work process $\rightarrow$ Complexity Stress/stressors $\leftrightarrow$ Fitness for duty Available time $\leftarrow$ Work process
(Boring 2010) [16]	Available time - Stress/stressors Work process - Experience/training Ergonomics/HSI - Fitness for duty	Available time $\leftrightarrow$ Stress/stressors

4 Future Work

The concept of PSF-based dependency presented here is still under development. In this paper, a direction on how to quantify dependencies using the new PSF-based dependency method is discussed. In the future, the methodology will be validated with a generic PSA model. Then, the results of dependency analysis will also be benchmarked with that from existing dependency methods. These will be explained in future treatments of this approach.

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Is Dependency in Human Reliability Analysis a Real Phenomenon? Refining the Dependency Concept Through Research

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Abstract. Dependency, specifically defined as the degree to which one erroneous action can impact subsequent actions, has been a fixture in many human reliability analysis (HRA) methods for the better part of forty years. Its incipience in the Technique for Human Error-Rate Prediction (THERP) was supported, seemingly, by examination of observed phenomena, but the documented evidence and link to proven psychological theories were absent. While HRA is typically a quantitative effort with qualitative inputs, we should be careful to ensure that HRA methods respect their psychological foundations lest the models constructed fail to measure the characteristics of human error accurately and sufficiently for the assessment of safety critical applications. This paper seeks to refocus attention on a foundational question in HRA—is dependence in a chain of human erroneous actions such that 'error begets error' a real phenomenon? Research is still needed to validate the construct and quantification of dependency.

Keywords: Human reliability analysis · Dependency · Human error · Cognitive ergonomics · Risk assessment

1 Introduction

A necessary step of most HRA efforts is the assessment of dependence between various actions and their corresponding human error probabilities (HEPs). In most methods, dependence acts as an operation or modifier on defined HEPs and can dramatically change those probabilities based on the dependence assessment. In the *Handbook for Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications*, which outlines the Technique for Human Error-Rate Prediction (THERP), Swain and Guttman argue that the problem of dependence is the need to determine how the success or error on a task affects the success or error probabilities on subsequent actions [1]. Additionally, the primary concern which dependency is trying to assuage is to ensure that a resulting estimate of human error is not overly optimistic and therefore the risk is not accurately captured. Many other HRA methods trace their lineage and the origin of the idea of dependency back to this explanation from THERP.

Definitional precision is key in this effort as dependency has become a bit muddied in recent research. There are two predominant forms of dependency considerations in

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HRA, specifically the dependence of performance shaping factors (PSFs) on other PSFs, and the dependence of previous action outcomes on subsequent success or failure. This paper is focused on the second form of dependence. In particular, tracing the literature back, it appears that dependence has a single origin point, THERP. Importantly, over the past decades, theories of human error have been put forth and are still a focus of ongoing research; however, the notion or idea of 'error begets error' or dependence is notably absent in these thorough considerations and accounting of human error. A similar lack of discussion of action dependence is found in the psychological literature outside the realm of human error. While there is psychological research on task batteries, which look at performance across a series of tasks, usually the batteries serve the intent to cover a range of human actions for particular contexts. Task batteries do not consider dependency between tasks, simply because the tasks are specifically designed to be varied. Some studies also consider practice effects across tasks – improvement in performance due to having recently performed a similar or identical task – but these are primarily found in unskilled tasks that readily benefit from learning and practice.

Identifying and weighing the relevant inputs of the infinite number of variables that affect performance is an incredibly complex task that involves a not-insignificant number of assumptions as well. Psychological science has made great strides in developing our understanding of memory, action, decision making, and other components of human thought. However, in this foundational research it is not clear that dependence has a role as a theoretical concept or an empirically observed phenomenon. It is not certain what purpose such a function would serve in our evolutionary development or behavior, or what structures in the mind would manage such a process. Therefore, this paper seeks to explore if dependency should be considered as a component of HRA generally.

The notion of dependency, then, is that if agent A takes action X and is unsuccessful then agent A will have a modified probability of success on action Y. There are several forms of dependence assessments, such as no dependence, complete dependence, or measures of partiality. The evaluation of this dependence, as often is the case in HRA methods, is a subjective determination made by a human reliability analyst. Additionally, THERP's dependence sections do not present or define exactly how an analyst would make the determination outside of other subjective measures such as expert evaluations. While this on its own isn't abnormal – as most of HRA has some subjective qualities – it still is a challenge to assess something like dependency in such an unspecified manner.

All of these concerns, when combined with the outsized effect dependency calculations can have on HEPs in many methods, brings a greater level of attention on dependency in general. The authors here seek to ask a foundational question of dependency as defined, primarily from a psychological perspective: Does dependency manifest in a manner consistent with these understandings? In terms of mechanical or system focused probabilistic risk assessment (PRA), the tight coupling and structural connections between components necessitate the consideration of dependency in treatments such as common cause failures. But, in HRA can we adequately say that one human error leads to subsequent human errors? The authors are not saying this phenomenon is impossible but are instead stating that more fundamental research is required before any positive assessment of its existence can be relied upon.

Such comments are not meant to be disparaging to the application of dependency in many HRAs. Dependency contributes to conservatism in risk analysis, which leads to greater safety. This outcome is commendable and should not be reversed. Likely, dependency captures contextual carryover from one action to the next that is not otherwise treated in the HRA. As such, dependency serves as a type of necessary correction factor in the HRA. Is dependency the right construct to capture this, or is there a need for a better modeling basis that can account for contextual carryover without the construct of dependency? Dependency, which acts as a mathematical treatment of currently aleatory phenomena, should not act as a surrogate for a better understanding of the phenomena underlying dependency. If dependency exists as a standalone construct, it will benefit from more rigorous study. If it is an artefact of another phenomenon, HRA will benefit from a systematic treatment of the underlying effect at play. Until such time as this important research can be completed, the existing dependency models and quantification should remain standard practice in HRA.

2 Types of Dependency and Their Impacts

THERP establishes three forms of dependency: independence, direct dependence, and indirect dependence [2]. Examples of the flow of actions in these situations is shown below in Fig. 1.

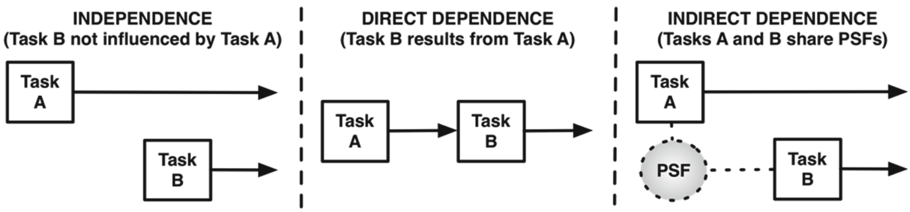

Fig. 1. Forms of dependence [3].

Additionally, THERP, Standard Plant Analysis Risk-Human (SPAR-H) [4], and other HRA methods break dependency into five categories: zero, low, moderate, high, and complete. These delineations give the analyst flexibility in applying dependency modifiers on broader HEP calculations. Due to the powerful effect that dependency can have on the assessment of human error, it was recognized that a light touch was necessary, allowing analysts to select lower levels as needed. The impact of the dependency adjustment is as follows: converging on 1/20 (0.05) for low dependency, 1/7 (0.14) for moderate dependency, 1/2 (0.5) for high dependency, and 1.0 for complete dependency [1]. So, the impact of a non-zero dependency is significant.

3 Dependency as a Construct

Critical in this effort is the need to define what dependency can mean, and how this paper treats the concept in terms of first principles. In the natural and chemical sciences, it may be a common stance that no events are ever independent. All events have some measure of cause and effect on other instances. To ground this in a nuclear operations example, a human error by an operator creates a reality or environment which includes that error's causes and effects. It is hard to refute that common context between human actions could have an effect on both outcomes, what Swain and Guttman would call indirect independence [1], as depicted in Fig. 1. However, they also posit direct dependence, which "exists when the outcome of one task directly affects the outcome of a second task" [1, p. 10-2]. They go on to explain that the error on the first task fundamentally changes something such that it primes the second error.

The present authors acknowledge this characterization of dependence where any action fundamentally changes the world around it in specific ways, and those permutations can have an impact on any following action or instance. However, this is a fundamentally different characterization than what is the case in HRA methods in practice.

When dependency is considered in HRA the contention is that an erroneous action *increases* the probability that a following action will also be erroneous. The notion here commonly referred to as 'error begets error.' As stated, it is almost certain that the initial erroneous action had an impact on the resulting reality, and those permutations very possibly change the circumstances of following actions. A particular argument is being made, however, in this definition of dependency, namely that when one human makes an error either the same human or different human(s) will also have an increased chance at making an error. This claim states something far broader than many have considered before, specifically that a preceding human error modifies the psychology and human cognitive processes at play in the same or different human minds. This argument the authors feel is under-supported at best and potentially not supported at all.

In the decades since THERP was first published, psychology has come to some key understandings of how human cognition and decision-making operate. There is an understanding of attention, memory, perception, heuristics, and other functions that are at play as humans navigate and interact with the world. With that said, there are still substantial amounts of information not known about how these processes unfold. For dependency to function as described in HRA methods then it is expected that the presence of a previous human error would have some impact on these underlying cognitive structures, but that does not seem likely *a priori* in considering how human cognition functions. The authors are not necessarily stating that there could not be such an effect but are instead calling attention to the fact that there does not appear to be robust evidence in favor of its existence currently.

In exploring this topic, the authors performed a literature search for psychological research on action or decision-making that may show this effect. The authors did not find psychological research considering dependence aside from substance dependence in addiction research, which is a fundamentally different sense of the word *dependenc*e. The authors also searched the three taxonomies that have heavily influenced research and thinking on human error—Rasmussen's Skills-Rule-Knowledge framework, Reason's Human Error, and Norman's Slips and Mistakes framework [5–7]—for analysis or information on the phenomenon. None of these taxonomies explicitly mentioned dependency or considered an idea similar to error begetting error. Tracking dependency back to THERP and related documentation brings another problem to light, namely that in the sections where Swain and Guttmann describe dependency as an idea and its role in HRA there are no references or citations to be found that trace the genesis of the concept.

The authors agree that dependency may have some explanatory power in human error or cognition but feel confident in stating that as of now there is little if any psychological research to show it as more than a hypothetical construct, much less to assume any realistic calculative effect on probabilities of human actions. There must be foundational psychological research completed to show its existence and validate its impacts. Until such time, the calculations used in HRA methods for dependency should be considered approximations. We ultimately advocate for increased precision in the treatment of dependency.

4 Dependency in HRA—Conservative Assessment of Risk

It bears mentioning that HRA is ultimately about assessing the risk of a particular nuclear plant's operations or the operations of comparable safety-critical systems. Every industry must manage risk, but the nuclear power industry has an obligation to manage their risk even more due to the high-profile nature of potential failures and potential harm to environments or populations. Some may make a claim that nuclear power is overly risk sensitive; however, the extremely infrequent large-scale failures and commitment to safety has paid dividends in making it an extremely safe industry across its many decades of time in deployment. HRA is a particularly important characteristic of this conservative risk position. By carefully identifying areas of human contribution to risk, nuclear facilities can be reasonably assured of safe and effective designs as well as decent control of the most unpredictable part of any operation, the human.

There is an argument to be made that the inclusion of dependency is a result of an abundance of caution in the assessment and management of risk in a sector which rightfully emphasizes caution and safety of the society it supports. However, it isn't clear how the inclusion of dependency makes the assessments any more accurate or conservative. The potential artificiality of any inflation in HEP may overemphasize the impact on some areas of a system's design or operation unnecessarily. At its worst, it could overshadow other risks that need to be considered. Additionally, the realities of an HEP close to or equal to 1.0 are not truly helpful to the risk analysis, as it isn't nuanced in a way which drives re-design or corrective action decisions. It also bears questioning if the inclusion of a measure which does not have adequate scientific foundation or quantification makes the overall risk assessment more flawed and could lead to poor decisions derived from the analysis. Again, our purpose is not to discard countless risk analyses that have considered dependency. Our purpose is to pave the way for new research that can support these analyses, either through redefinition of the modeled construct of dependency or stronger empirical tie-ins to psychological phenomena.

5 Discussion and Next Steps

Fortunately, though assessing dependency may have outsized or unfounded impacts on the HEP, it is often applied through qualitative analysis by HRA methods and analysts.

This qualitative step hopefully injects some additional consideration in the potential effects that may prevent its use in situations that may not merit such a modifier. The irony of expecting human reliability analysts employing qualitative analysis and their own decision-making in the course of assessing human error likelihood in others should not be lost on anyone, and therefore there is a need for attention and additional research on the matter.

Of immediate need is a better understanding of dependency between human failure events as a concept and an examination of incident reports by human factors practitioners and researchers to understand where there have been incidences of something that resembles the standard characterization of dependency. As stated, the authors do not think that dependency as defined in HRA methods has a cognitive basis, but that assumption needs validation and alternative explanations put forth if there have been cases that disagree with that statement.

Next, foundational research in human error and human error chaining needs to be undertaken. Psychological research on human error has some challenges in adequate experimental design and validity due to the need to identify often low-probability events. Rare events may inherently lack statistical power, a problem that is compounded by the equal rarity of many of the target personnel. Reactor operators, for example, remain a highly selective population that may prove difficult to sample adequately for inferential conclusions. However, a better empirical understanding of the underpinnings of human error could yield substantial benefits to all industries, including nuclear. As nuclear power is highly proceduralized and a large investment is made in training and practice, a better understanding of how to prevent human errors, which are, by definition, unintentional acts, can only help increase the efficacy of these efforts. Additionally, if dependency is a phenomenon that needs to be assessed in HRA, fundamental psychological research on human error is likely our best chance at bringing it into the light.

Another key component of such human error research is more information on PSFs. PSFs are a prime sticking point for many methods, and each method has a different system or scheme to handling them. Human cognition is not so varied that such research would not result in a sharper, clearer understanding of the various things that can impact human action and decision-making. This clarity may finally yield a robust, empirically based, and comprehensive list of the factors that affect human performance when using high-risk and high-consequence systems. Such factors may also be the underlying continuity that results in indirect dependency, not as a standalone phenomenon but as a byproduct of common contexts throughout human activities.

In conclusion, the concept of dependency between HFEs does not appear to have a robust or well-sourced lineage in psychological research. The impacts of dependency calculations can be significant on an overall HRA. Therefore, the authors believe research should be undertaken to better understand and begin to demonstrate the characteristics of human error and any potentially covariate effects.

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Formative vs. Summative Dependence in Human Reliability Analysis

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Abstract. Dependence in human reliability analysis (HRA) is the concept that once an initial human error has occurred, subsequent human errors are more likely. The approach almost universally adopted in HRA was first introduced in the Technique for Human Error Rate Prediction (THERP). In THERP, calculated human error probabilities (HEPs) are adjusted for dependence in the final step of quantification. This final adjustment for dependence involves anchoring the HEP to a set of values corresponding to low through complete dependence. The effect is to increase the HEP. In this paper, we propose formative dependence, which occurs at the onset of quantification. We demonstrate that dependence should be considered earlier in the calculation process, because it is not actually necessary to calculate the HEP when it is subsequently overridden by the dependence anchors. By applying dependence first in the calculation, processing steps can be eliminated, making for more efficient analysis.

Keywords: Human reliability analysis · Dependence analysis · Formative process

1 Introduction

Dependence as a concept in human reliability analysis (HRA) originated in the Technique for Human Error Rate Prediction (THERP) [1]. In THERP, Swain and Guttmann introduced the idea that with the occurrence of one human error in a human action sequence, subsequent human actions would have an increased likelihood of human error. The idea that error begets error was called direct dependence, suggesting a direct effect of one action on the next actions. If there is no relationship between the tasks, they are said to be independent. If they share a moderating variable like the influence of common performance shaping factors (PSFs), this effect is known as indirect dependence. These three types of dependent relationships are found in Fig. 1. Additional types of dependence relationships have recently been explored in [2], suggesting these three THERP categories may not be exhaustive.

THERP did not elaborate on the precise mechanisms for direct and indirect dependence. For direct dependence, correction factors for dependence are provided for positive and negative levels of dependence. Negative dependence occurs when failure on the first

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task decreases the chance of failure on a subsequent task or increases the chance of success. This form is rarely modelled in contemporary HRA. Positive dependence, the more prevalent form, occurs when failure on the first task increases the chance of failure on subsequent tasks. The equations for positive dependence are provided in the next section.

THERP's foundational work on dependence has carried forward into most modern HRA methods, including use of the same correction factors. It is worth noting, however, that dependence in THERP considered dependence between human tasks, not between human failure events (HFEs) [3]. Dependence in THERP is linked to a type of subtask analysis using now-rare HRA event trees. The concept of dependence has nonetheless generalized well to the subtask-aggregated HFEs used in contemporary HRA. While THERP established the concept and calculations almost universally used in HRA today, the actual unit of analysis used for THERP dependence is now superseded.

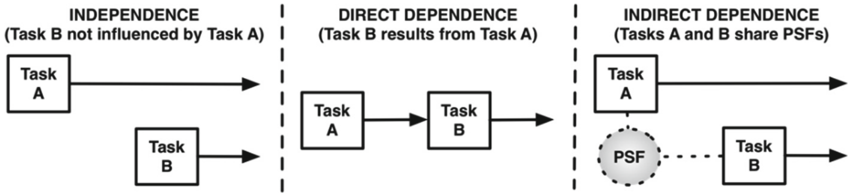

Fig. 1. The relationship between tasks in terms of dependence [3].

2 Dependence Calculation

Starting with THERP and carried forward in most HRA methods, there are three stages in calculating the HEP:

1. *Nominal HEP (NHEP):* This is the starting or default HEP value. It is typically linked to a lookup table that matches particular human activities to predefined HEP values. Some methods like THERP provide an extensive list of these nominal HEPs, while simplified methods will only provide a few values. For example, the Standard Plant Analysis Risk-Human (SPAR-H) method [4], a simplified HRA method, delineates only two nominal HEPs for diagnosis vs. action tasks.
2. *Basic HEP (BHEP):* Next, influences are considered that could drive the HEP up or down relative to the Nominal HEP. These influences are commonly captured using PSFs. HRA methods each have unique PSFs, but they largely converge on a set of characteristics that are known to degrade performance. These degradations systematically increase the Basic HEP relative to the Nominal HEP. Many HRA methods also consider the positive effects of PSF, which enhance performance and systematically decrease the Basic HEP relative to the Nominal HEP.
3. *Conditional HEP (CHEP):* Finally, dependence and recovery are considered. Here, we only treat dependence. Dependence increases the HEP when there is a conditional link to a precursor HFE. The corrections applied to the Basic HEP in consideration of

dependence are found in Table 1. As noted, these equations first appeared in THERP and continue to be used by most HRA methods that formally treat dependence. The dependence calculations are based on five levels of dependence, spanning zero (ZD), low (LD), medium (MD), high (HD), and complete dependence (CD). These levels are assigned by the analyst in accordance with guidance specific to each HRA method.

Table 1. Conditional HEP calculations for different levels of dependence.

Level	Calculation
Zero	$CHEP = BHEP$
Low	$CHEP = \frac{1 + 19 \times BHEP}{20}$
Medium	$CHEP = \frac{1 + 6 \times BHEP}{7}$
High	$CHEP = \frac{1 + BHEP}{2}$
Complete	$CHEP = 1.0$

The effects of dependence can be seen in Fig. 2. Dependence essentially serves to anchor the Conditional HEP to a higher HEP than the Basic HEP. For low dependence, this anchor is around 1/20 (5E−2); medium dependence, 1/7 (1.42E−1); high dependence, 1/2 (5E−1); complete dependence, 1. For zero dependence, the Conditional HEP remains unchanged from the Basic HEP.

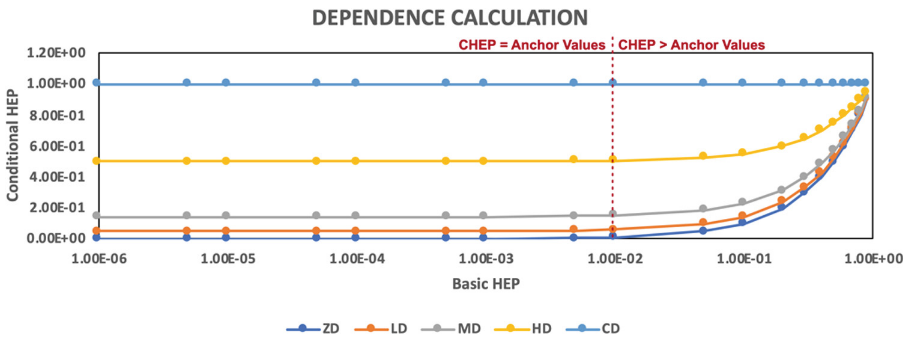

Fig. 2. The relationship between the basic and conditional HEPs.

3 Formative Dependence

Calculating dependence is the last step in conventional HRA quantification. Yet, by anchoring the HEP to a few values, dependence essentially overrides the prior quantification steps. It seems that calculating the Nominal and Basic HEPs are unnecessary steps if the Conditional HEP independently determines the end result. In the remainder of this paper, we review the possibility of foregoing the calculation of the Nominal and Basic HEPs when dependence is at play. Instead, we propose simply setting the Conditional HEP to the dependence anchor values: 5E−2 for low dependence, 1.42E−1 for medium dependence, 5E−1 for high dependence, and 1.0 for complete dependence. In this approach there is, in fact, no calculation necessary, since the Conditional HEP is simply set to these constants.

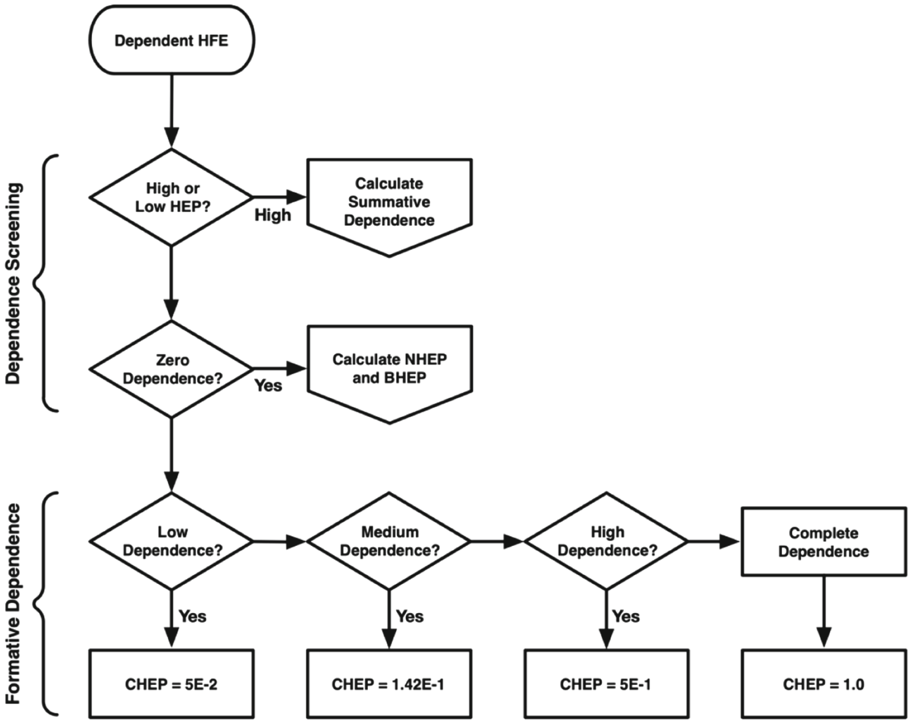

Fig. 3. The formative dependence process.

We call this approach of assigning predefined values to the Conditional HEP *formative dependence*. The basic method for formative dependence is depicted in Fig. 3 and elaborated in the remainder of this section. Formative is a term derived from education, to suggest the influence helps form the end state [5]. Formative implies a presence early in the process, contrasting with summative, which occurs at the end or sum of the process. The distinction between formative and summative has been adopted by the field of software design and evaluation—formative evaluation occurs during the design process, while summative evaluation occurs after the completion of the design [6]. Formative evaluation helps form the design, while summative validates that the design as completed performs as it should. Similar terminology can be applied to dependence. Formative dependence is the application of dependence at the onset of HEP quantification. *Summative dependence*, representing dependence quantification as currently practiced, occurs at the conclusion of the HEP quantification. Because the effects of dependence when using the THERP correction factors override other calculations, we posit that formative dependence will result in the same outcomes as summative dependence. Applying constants for Conditional HEPs when dependence is assumed eliminates many quantification steps. In turn, formative dependence can result in significant efficiencies for calculating large cutsets in HRA that consider dependence.

A screening approach provides an approximate, conservative answer that can be used in models to determine the risk significance of the resulting HEP when placed in the overall probabilistic risk assessment (PRA) model, which includes hardware and human risk. If an HFE is risk significant—in nuclear power, commonly meaning the effect of the human failure increases the core damage frequency or large early release frequency [7]—then a more detailed HRA is warranted to arrive at a realistic HEP. If it is not risk significant, there may be little need to perform a more detailed analysis. This screening approach is predicated on the screening HEP value being likely more conservative than the realistic HEP. In other words, screening posits a type of worst-case human performance to see if it has any negative effect on overall plant risk and safety.

Formative dependence would appear to be a type of screening analysis—if not explicitly a worst-case HEP then at least an HEP based on conservative dependence anchor values. The challenge with formative dependence is that it will not always represent a conservative estimate. Anchoring the HEP to the values of 5E−2, 1.42E−1, 5E−1, and 1, respectively for low, medium, high, and complete dependence, elevates the Conditional HEP to a higher value than the Basic HEP in most cases. When the anchor values are higher than those values resulting from a detailed calculation of the Basic HEP, then applying anchor values as surrogates for the Conditional HEP would be analogous to screening for dependence. However, there remain cases where the calculated Conditional HEP exceeds the anchor values. Applying the dependence calculations from Table 1 will always increase the Conditional HEP relative to the Basic HEP. Only when the Basic HEP values are lower than the dependence anchors will it bring the Conditional HEP up to the anchor values. Otherwise, it will exceed them.

Figure 2 presented the relationship between the Basic and the Conditional HEPs. This graph demonstrated that up to a threshold value, the Conditional HEP equaled the dependence anchor values. Above this threshold, the calculated Conditional HEP exceeds the dependence anchor values. Figure 4 more clearly illustrates the differences between calculated Conditional HEPs and the anchor dependence values. For Basic HEP values of 5E−2 or more, anchor dependence values are systematically lower than calculated Conditional HEPs. It therefore appears formative dependence works well as a surrogate only when the calculated HEP is below the threshold of the dependence anchors. This finding suggests a bounding rule is necessary for formative dependence:

Rule 1: Apply dependence anchors for a Basic HEP $\leq$ 5E−2

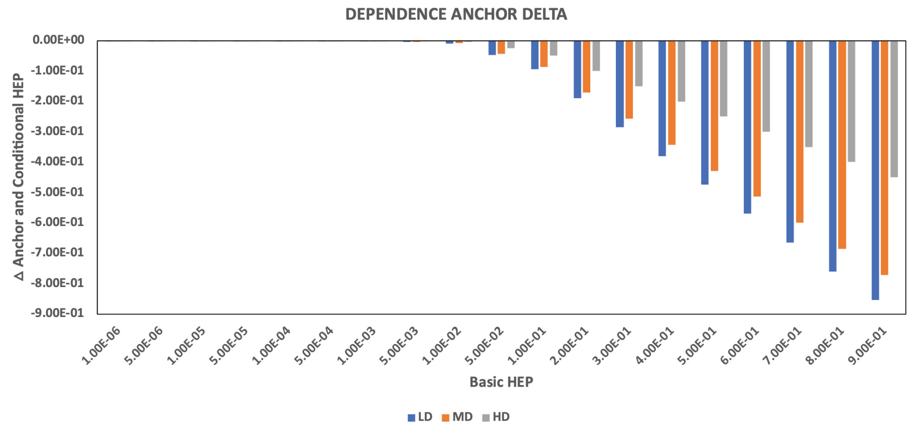

Fig. 4. The difference between anchor and conditional HEPs for dependence levels.

Formative dependence uses the dependence anchors instead of calculating the Conditional HEPs, but dependence anchors appear to forego conservatism above the Basic HEP threshold of 5E−2. It remains a bit of a chicken-and-egg problem to determine if formative dependence is applicable when the value it supplants also needs to be calculated. It is impossible to tell if the dependence anchor substitution represents a conservative screening value without first performing the more detailed HEP quantification through Nominal, Basic, and Conditional HEPs.

In practice, HEPs for many HFEs will be below the threshold of 5E−2, in which case using dependence anchors will not understate the risk. The exact proportion of HEPs below this threshold will vary by application, but many analyses will remain safely in range for formative dependence. Nonetheless, if there is reason to believe that the calculated Basic HEPs would exceed 5E−2, it is necessary either to calculate the HEP or to estimate it using a screening approach:

Rule 2: Perform a screening analysis to determine if the Basic HEP > 5E−2

To perform a formative dependence analysis for higher Basic HEPs, an initial estimation must be performed to determine the likelihood of the human error for that HFE. Two approaches are suggested:

1. An overall screening analysis may be performed on the HFE in the PRA. Screening may be accomplished by selecting the next higher level of dependence. If the chain has low dependence, for example, risk-significance screening may be accomplished using the value of medium dependence. If the event is determined not to be risk significant, it may be reasonable to use the dependence anchors instead of calculated Conditional HEPs with the knowledge that the values may not represent risk conservatism.
2. Alternately, the analyst may perform a quick screening calculation of the HEP to determine if it is high likelihood, specifically greater than 1E−2. Standard screening approaches such as ASEP [8] or expert estimation [9] may yield quick estimations

of the magnitude of the HEP sufficient to gauge if the HEP is greater than or equal to 1E−2. High likelihood human errors warrant a detailed analysis and should forego the use of formative dependence.

Using screening values may resolve the challenge that even when using dependence anchors, there is no default value for the zero-dependence condition. Recall that in the case of zero dependence, the Conditional HEP is the same as the Basic HEP. If no Basic HEP has been calculated, however, there is no value to assign in the dependence case:

Rule 3: For zero dependence, the Basic HEP must be calculated

Thus, either a screening value or a value calculated per the HRA method must be used for the Basic HEP.

These rules are incorporated in the formative dependence process outlined earlier in Fig. 3. An initial screening (*Rule 2*) is performed to see if the HEP is high or low. If the HEP is high (i.e., BHEP > 1E−2; *Rule 1*), the analysis is directed toward the conventional summative HEP process. If the HEP is low, the flow next considers zero dependence. If there is zero dependence (*Rule 3*), the analysis is directed to calculate the Basic HEP. If the three rules do not branch the analysis to the need to perform HEP calculations, the formative dependence process is applied.

4 Conclusions

Formative dependence provides a reconsideration of the conventional order of applying dependence as a tail-end activity. Because the dependence correction factors replace the calculated HEPs from conventional summative dependence, formative dependence eliminates the need for knowing the Nominal or Basic HEP. Formative dependence affords significant efficiencies over summative dependence. However, the approach may not exhibit HEP conservativism for high HEP values. The utility of the approach may therefore be limited to cases of dependence for known low HEPs.

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Human Error of a System Based on FMEA

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Abstract. Many studies and system accidents have shown that human factors, such as illegal operations, fatigue work, and weak theoretical knowledge, are the main reasons for system accidents or incidents. Under the background of Man-Machine-Environment system, it is undoubtedly of great practical significance to contemporary society to study the accidents caused by human errors in the system and find a countermeasure for effectively controlling human errors in the system. This article follows the qualitative and quantitative analysis and research ideas, using Failure Mode and Effect Analysis (FMEA) and fault tree analysis (FTA) to study the human error in the man-machine interface of a certain equipment system.

Keywords: Human error · FMEA · FTA · Human-computer interaction

1 Introduction

At present, 60%–90% of various accidents are caused by human error [1]. According to data [2], human errors account for at least 70%–80% of the total number of aircraft accidents or incidents in the aviation industry. In recent years, with the development and progress of science and technology, human errors have increased year by year. Therefore, the human error of the system must be studied.

In the understanding of human error, experts in various fields also define it from different perspectives. Reason [3] proposed that human error is that people have not achieved the expected results after a series of physical activities and psychological operations. Li Zhang [4] believes that human error should be defined as the failure of planned actions performed by humans to complete tasks. Pengcheng Li [5] believes that human error is divided into potential human error and manifest human error. While the research based on the theory of human error has become more mature, experts have launched a deeper research on human error. Xin Yu [6] combined FMEA(failure mode and effect analysis) and structural entropy to study human errors during gearbox assembly. Xuanxuan Li [7] adopted the SHELL model and the FMEA method improved by the IFHWED operator to establish a medical equipment human factor reliability evaluation model. Ruofei Xu [8] used SHERPA(Systemic Human Error Reduction and Prediction) method and FMEA method to study the interactive design of medical APP for the elderly.

The research object of this paper is a certain equipment system, which requires extremely high accuracy and efficiency of its operation, and its efficiency is the general

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goal pursued by the development and use of this system. Any system is composed of human, machine and environment. In order to optimize the efficiency of the system, the three must be reasonably integrated. This article mainly studies the relationship between human and machine.

2 Overall Design

The research of human error in the system mainly uses FTA method and FMEA method. This article takes a certain equipment system as the research object, combines the FMEA method with the FTA method, and conducts qualitative and quantitative research on human error. The main research work includes:

(1) Use SHERPA method to layer the event tasks, draw Hierarchical Task Analysis(HTA) charts, experiment and count the error mode and the number of errors, and then determine the type of error. Analyze the error type failure mode by FMEA method, and then calculate its Risk Priority Number(RPN) according to the severity(S), occurrence(O), and detection(D) and rank.
(2) Use the FTA method to analyze the failure mode of RPN $\geq$ 120, find its cause and logical relationship, establish a fault tree model to graphically illustrate it; then find the minimum cut set of the fault tree and calculate the probability of failure events In order to find the core factor of the failure event.
(3) Finally, according to the failure event, the system is improved from the perspective of the operator's physiological, psychological and human-machine interface design, and the feasibility is verified by comparing the performance before and after the improvement.

3 Case Study

3.1 Sherpa

The operating system interface of an equipment system includes four interface elements A, B, C, and D. The display includes interface element A and interface element B, and the controller includes interface element C and interface element D, as shown in Fig. 1.

Perform SHERPA analysis and draw HTA task diagram for an existing operating system interface, as shown in Fig. 2. The Body Setting is an indispensable operation stage of the system. Therefore, this study mainly analyzes the Body Setting function of the system. The HTA analysis diagram is shown in Fig. 3.

Invite 10 operators to operate the tasks of the Body Setting function in Fig. 3 in the order of operation. And according to the experiment and SHERPA error analysis, the experimental data of the system before improvement in Table 1. The average number of errors made by the experiment operator during this operation process is 2, of which the most error type is A4.

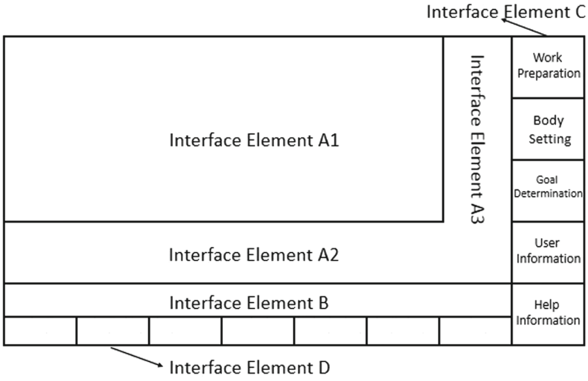

Fig. 1. A system interface layout.

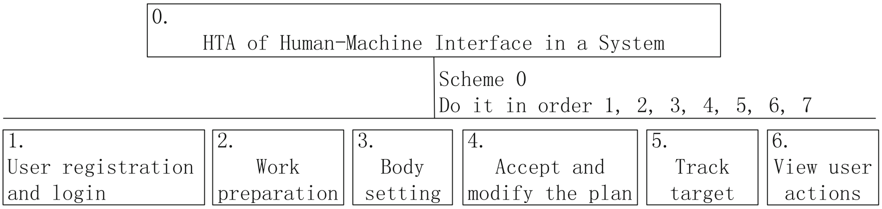

Fig. 2. HTA of Human-Machine in a System.

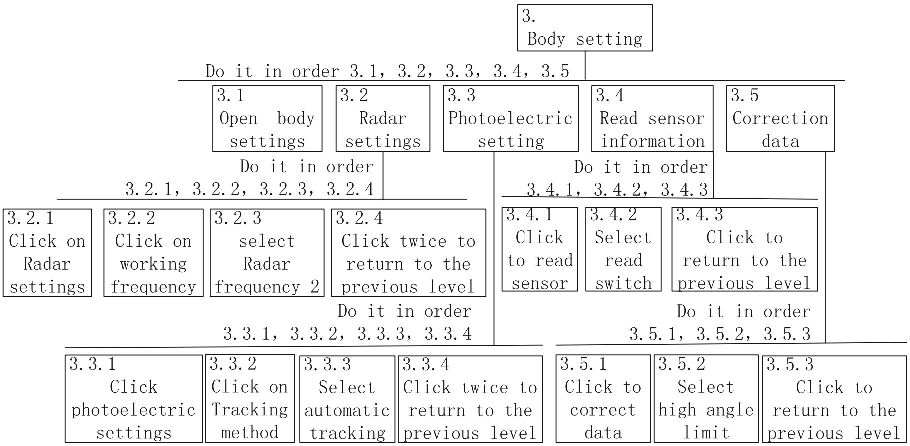

Fig. 3. HTA of Body Setting function.

Table 1. System test data before improvement.

Error type	Number of errors
A: Operating in the wrong direction	2
B: Too many/too few operations	7
C: Position deviation/displacement during operation	4
D: No search information	2
E: No exchange information	5

3.2 FMEA

FMEA is a bottom-up inductive analysis method, usually divided into two steps.

Determine the Failure Mode of the Error Type. According to SHERPA analysis, the types of human manipulation errors in a certain system interface are: A, B, C, D, E, and an in-depth analysis of its potential failure modes is shown in Table 2.

Table 2. Failure mode analysis of body setting function.

Error type	Task steps	Potential failure mode	Potential failure cause	Potential failure consequences
D	3.1	Can't find the body set key	There is a problem with the page layout	Can't proceed to the next step
A	3.2.1	Click the gray unselectable button	Lack of error description	Cause emotional anxiety
C	3.3.2	The key is to press the next option	The option box is small and the setting is unreasonable	Affect subsequent operations
B	3.4.3	Return key press less/more times	Unreasonable design	Can't return to the specified page
E	3.5.2	Forget the next step	No prompt to the operator	Affect work efficiency

Calculate RPN. Invite 5 experts to rate the S, O and D of potential failure modes, with a maximum score of 10. The larger the value, the more serious the failure mode, the more likely it is to occur, and the more difficult it is to detect. Finally, the average integer value of 5 experts is taken as S, O and D. Calculate RPN, and then sort the failure modes according to the magnitude of the risk sequence value to determine whether there is a need for improvement or the priority of improvement, as shown in Table 3.

According to Table 3, there are 3 error types with RPN greater than 120. The error types are A4, I1, and A5. A4 has the largest RPN. Therefore, the failure mode of error type A4 will be analyzed qualitatively and quantitatively in the fault tree, and the potential failure causes of the two error types are directly improved.

Table 3. Numerical calculation and ranking list of risk sequence.

Task steps	Error type	S	O	D	RPN (RPN = S × O × D)
3.4.3	B	6	7	4	168
3.5.2	E	5	5	5	125
3.3.2	C	6	4	5	120
3.2.1	A	3	2	3	18
3.1	D	7	2	4	56

3.3 FTA

FTA is a top-down logical graphical analysis method developed by Watson and Hansel [9], which aims to determine the cause and possibility of failure events. Generally, FTA is divided into three steps.

Build Fault Tree. According to the FMEA, the failure mode with the largest risk sequence value in the system is that the operator presses the return key less/more, and the potential failure consequence is that the specified page cannot be returned. Therefore, this fault tree analysis regards the failure to return to the specified page as the number one event, analyzes the cause of the number one event and the relationship between the causes, and then analyzes to find the deeper reasons until the deeper reasons are not found. Connect the discovered events with logical symbols to construct a fault tree of the car body setting function, as shown in Fig. 4.

Qualitative FTA. According to Fig. 4, it can be seen that each basic event can independently cause the number one event to occur. Therefore, the 11 basic events in the fault tree are the minimum cut sets. For the improvement of the system, full consideration should be given to the basic events that lead to the number one event "cannot return to the specified page" in Fig. 4. For example, by setting reasonable working hours to avoid operator fatigue, so as to reduce the occurrence of stiffness, slow response and symptoms of blurred vision; through more simulation training for operators, to avoid lack of experience and improve their working ability.

Quantitative FTA. The fault tree has a total of 11 minimum cut sets. This time, 50 operators are invited to collect the number of occurrences of the minimum cut set through investigation, and calculate the probability of the occurrence of basic events. The data after one treatment is shown in Table 4.

According to Table 4, it can be seen that the highest probability of basic events is too many frame levels, followed by blurred vision, lack of experience, lack of explanation of icons, rigid movements, and lack of self-confidence. Regarding the order in which the probability of occurrence of the basic event is the system's improvement, it is improved.

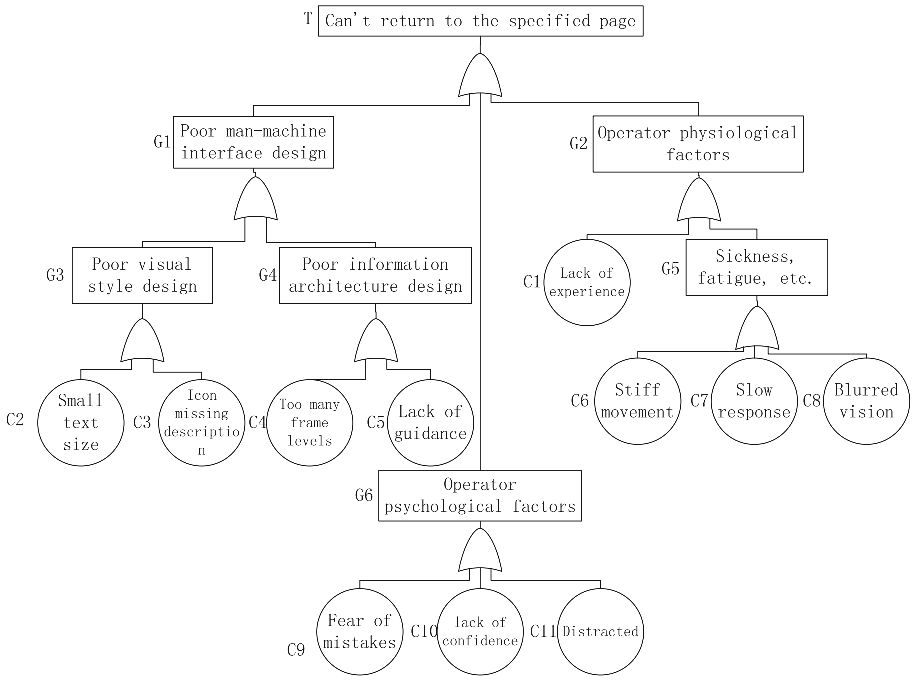

Fig. 4. FTA of a system's man-machine interface car body setting function.

Table 4. Probability of basic events.

Major factor	Secondary factors	Frequency	Probability of occurrence
Poor visual style design	Small text size	2	0.04
	Icon missing description	1	0.02
Poor information architecture design	Too many levels of framework	18	0.36
	Lack of guidance	4	0.08
Operator physiological factors	Lack of experience	6	0.12
	Stiff movement	1	0.02
	Slow response	2	0.04
	Blurred vision	9	0.18
Operator psychological factors	Fear of mistakes	2	0.04
	Lack of confidence	1	0.02
	Distracted	4	0.08

3.4 Design Improvement

This article draws out the problems of the system through analysis, and improves the system from both the machine and human aspects based on the analysis results.

Improve the Machines in the System. According to the data in Table 4, the basic event "too many levels of framework" has the highest probability, followed by "lack of guidance". The improvement of the machine in this system is mainly aimed at these two aspects.

To address the problem of too many framework levels. Too many levels of the framework lead to complex operation procedures. In this system, the main manifestation is to return to the main page from the sub-menu. The number of times the return button is clicked varies according to the number of operations, the operation time is long, and the operation procedure is cumbersome. To solve this problem, add a button to return to the main page in the interface.

To address the lack of guidance. The operator's stuttering during the operation, the lack of guidance on the man-machine interface, etc., are caused by the fact that the operator does not know how to reach the specified page or has an operation error but does not know it. When the operator is operating, the man-machine interface guides the operator's operation, so that the operator can recognize the purpose of the operation and whether the operation is correct, and improve work efficiency. Figure 5 shows the improved effect map for this problem.

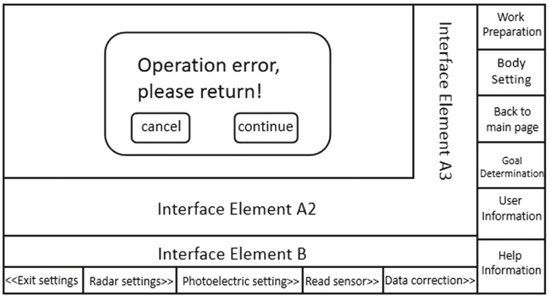

Fig. 5. The improved man-machine interface rendering.

Improve People in the System. It can be seen from Table 5 that people in the system are prone to accidents that cannot return to the specified interface due to lack of experience and blurred vision during work. When improving the people in the system, the two aspects of inexperience and blurred vision are mainly improved.

Aiming at the problem of insufficient operator experience. Before the operators begin their formal work, they should be trained in a unified pre-job and set corresponding qualification standards. Only after they meet the qualification standards can they be allowed to work, and regular assessments are required after they are on the job. When the operator has sufficient experience, he will have confidence in his operation, and he will no longer be afraid of accidents due to operation errors.

Aimed at the problem of blurred vision of the operator. The blurred vision of the operator is mainly caused by fatigue. In order to improve the reliability and work efficiency of the system, the original workload should be reduced to ensure that the operator is full of energy and concentration while working, and avoid blurred vision.

3.5 Result Verification

According to the improvement plan of the machine and people of the system, the system is tested again. In this experiment, 10 operators of the previous experiment were also asked to improve. According to the comparison of RPN values before and after improvement in Table 5, the RPN values after improvement are all lower than before and all RPN values are ≤120. It can be concluded that this improvement plan is feasible.

Table 5. Numerical calculation and arrangement of RPN before and after improvement.

Task steps	Error type	RPN before improvement	Improved RPN
3.4.3	A4	168	72
3.6.2	I1	125	50
3.3.2	A5	120	60
3.2.1	A3	18	9
3.1	R1	56	28

4 Conclusion

This article follows the qualitative and quantitative analysis and research ideas, and analyzes the human error of a system's man-machine operation interface by combining the FMEA method and the FTA method, so as to find an effective countermeasure to control the human error in the system. Specifically, the following three conclusions are drawn: (1) Use the SHERPA method to layer event tasks in a system's man-machine interface operation, and summarize the error types of the target tasks; (2) use the FMEA method and FTA method to analyze the failure mode, and find the fundamental event of the failure mode of RPN ≥120; (3) Finally, according to the failure event, the system is improved from the perspective of the operator's physiology, psychology, and human-machine interface design, and the feasibility of implementation is verified by comparing the performance before and after the improvement.

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Challenges and Opportunities of Applying the Human Reliability Analysis (HRA) Techniques for the Petrochemical Industry in China

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Abstract. It is widely acknowledged that human error is one of the significant reasons to trigger over half of the accidents. So far, dozens of HRA approaches have been published for qualitatively and quantitatively assessment to human error. However, most of the HRA techniques are sourcing from the nuclear industry, so people from the Chinese petrochemical industry may not be familiar with those nuclear industry-based HRA methods. Although we deem that HRA techniques could provide considerable benefits to safety management, directly using those methods in the petrochemical industry may cause some unexpected issues, since HRA is a relatively new idea to the petrochemical industry in China. Therefore, this study conducts a well-designed questionnaire survey to indicate the opportunities and challenges of the future HRA application in the petrochemical plants of China. This survey indicates the attitudes, opinions, and the potential barriers of practicing HRA methods in the petrochemical industry. The people involved in the questionnaire survey are all from the Chinese petrochemical industry, including management team and front-line operator.

Keywords: Human reliability analysis · Questionnaire survey · Chinese petrochemical industry · Challenges and opportunities

1 Introduction

Human error is one of the significant reasons to cause accidents. According to many published reports and statistical data, over half of the accidents are directly associated with human error [1]. Some experts from Chinese petrochemical industry have also realized that human error plays a key role in triggering accidents. In order to assess human error, dozens of HRA techniques have been designed and published, and these techniques have been successfully used for predicting Human Error Probability (HEP). However, the majority of those published HRA methods are based on the nuclear industry, and they are not broadly practiced in the petrochemical industry of China. Although the petrochemical industry has many similarities with the nuclear industry, they still have

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considerable differences such as nuclear radiation and power generation. Therefore, it is necessary to give a survey to indicate the challenges and opportunities of conducting HRA procedures for the Chinese petrochemical industry in future.

Before starting the survey, it is required to provide a brief literature review about the development of the HRA techniques to let readers can more understand their background. So far, the published HRA techniques can be divided into three generations. Among them, the first and the second generation of HRA methods are mostly applied in real practice [2].

The well-known first generation HRA methods are Technique for Human Error Rate Prediction (THERP), Human Error Assessment and Reduction Technique (HEART), Simplified Plant Analysis Risk Human Reliability Assessment (SPAR-H), and Success Likelihood Index Methodology (SLIM). THERP is the first HRA technique for commercial use. This method is designed and published in 1980s. It through evaluating Performance Shaping Factors (PSFs) to estimate HEP by human factor event tree analysis [3]. Although THERP is initially designed for the nuclear industry use, so far, it has been developed and expanded to other hazardous industries such as the offshore oil and gas domain [4]. HEART is another famous HRA technique which is designed by the British nuclear industry [5]. Similar with THERP, HEART procedure also requires the evaluation of many related PSFs, but HEART is more friendly in real application. It adopts certain mathematical equations to predict the HEP data, so it will not require large time to construct a human factor event tree. HEART has also been successfully applied to the process industry [6]. SPAR-H is the simplified version of THERP, it selects eight PSFs to assess human reliability through the certain mathematical equation [5]. SLIM is another simple first generation HRA method, its main idea is to use a small set of PSFs to estimate HEP data [7]. Although the first generation HRA techniques have been broadly practiced, their true capabilities are always questioned and criticized, since these techniques mainly focus on task and forget the importance of human cognition and environment in which task is performed [8]. As a result, the second generation HRA methods have been designed to improve the HRA quality.

Cognitive Reliability and Error Analysis Method (CREAM) and A Technique for Human Error Analysis (ATHEANA) are the two representatives of the second generation HRA techniques [9]. For ATHEANA, it is based on the nuclear industry, but it is a time-consuming method and weak in quantitative analysis, so this method is limited in use [5]. CREAM is one of the most well-known HRA techniques. This method gives consideration from the aspects of environment and cognitive. It utilizes nine PSFs to determine four contextual control models, and then to predict the final HEP value [2]. So far, CREAM has been applied in a broad range of industrial sectors. However, the second generation HRA techniques still have limitations. The way to conduct cognitive analysis in this group of HRA methods is too simple to reflect why human error occurs.

The limitations in handling cognitive analysis significantly weaken the quality of the results derived from the previously mentioned HRA techniques. Therefore, in recent years, researchers have developed some new HRA techniques through strengthening the function on cognitive analysis. Two famous new methods are IntegrateD Human Event Analysis System (IDHEAS) and Phoenix. Supported by the U.S. Nuclear Regulatory Commission [10, 11], IDHEAS absorbs many positive features of currently used HRA techniques. For example, the tree analysis method is still adopted by the IDHEAS method to ensure the HEP prediction is traceable. Besides, compared with other previously designed HRA techniques, IDHEAS has the stronger function in dealing with cognitive analysis [9]. Similar with the IDHEAS, Phoenix method also selects tree analysis method to form a traceable HEP estimation, and it focuses more on the cognitive psychology [10]. In addition, according to the framework of the Phoenix, a Petroleum Refining Operations (PRO)-based HRA method (Phoenix-PRO) has been developed [12].

Through learning the brief review of the HRA techniques, we find that, from the 1980s to present, the technique of HRA keeps moving forward. Researchers have made considerable efforts to address the limitations of HRA techniques. Besides, it can be concluded that most of the HRA methods are originally from the nuclear industry, rather than the petrochemical industry-based. Considering the differences between the nuclear industry and the petrochemical industry, directly introducing those HRA techniques into the petrochemical industry in China may cause some unpredictable issues. Therefore, the aim of this study is to investigate the challenges and opportunities for applying HRA techniques to the Chinese petrochemical industry in future years. The rest parts of this study are arranged as follows. Section 2 describes the methodology used for surveying in this study. Section 3 presents the data collection and analysis for indicating the challenges and opportunities for applying HRA techniques in the Chinese petrochemical industry. Finally, Sect. 4 concludes all the findings in this study.

2 Methodology

Questionnaire survey is a widely applied approach to extract or identify valuable information for safety management [13], so it is the main method used for this study. All the participants in this study come from safety-related positions in petrochemical plants owned by the Sinopec (the largest petrochemical company in China), so we can guarantee that our questionnaire survey is effective and reasonable. A total 202 people joined this research, and we received 197 effective questionnaires, so the response rate is 97.5% which is acceptable for an interview survey [14].

A specific questionnaire was designed for collecting data (see Fig. 1). The questions cover demographic information, people's opinions on human error, and people's experience and attitudes on HRA. By analyzing the feedbacks from each participant, we can find the opportunities and challenges of using HRA in the Chinese petrochemical industry. Before distributing this designed questionnaire, the objective, the requirement, and the content of this survey were introduced to each participant. Besides, people were also encouraged to ask questions to make sure they could fully understand this designed questionnaire. Among 197 effective participants, the number of male people is 176 and that number of female people is 21. The average age of all participants is 41.9 years old with Standard Deviation (SD) 8.9 years. The average working experience of 197 people is 20.3 years with SD value 10.0 years. Five-point Likert-style scale is selected to describe the options of some questions.

Questionnaire

1. Age:

2. Related working experience (years):

3. Gender:

4. Professional title and position:

5. To what extent do you agree that human error is a key factor to trigger accidents?
A. fully disagree, B. mostly disagree, C. neutral, D. mostly agree, E. completely agree.

6. In your working experience, to what extent do you believe that the abnormal and hazardous situations are associated with human error?
A. seldom, B. occasionally, C. sometimes, D. frequent, E. very frequent.

7. In your working experience, to what extent do you believe that the accidents are associated with human error?
A. seldom, B. occasionally, C. sometimes, D. frequent, E. very frequent.

8. In your working experience, to what extent do you believe that the abnormal and hazardous situations are directly associated with human error?
A. seldom, B. occasionally, C. sometimes, D. frequent, E. very frequent.

9. In your working experience, to what extent do you believe that the accidents are directly associated with human error?
A. seldom, B. occasionally, C. sometimes, D. frequent, E. very frequent.

10. In your working experience, have you experienced some HRA practices?
A. yes, B. no.
(If you select option A, then please continue to question 11; if your selection is option B, then please jump to question 13).

11. To what extent do you understand the HRA techniques you have learned?
A. Just heard of, B. limited understand, C. medium understand, D mostly understand, E. fully know how to conduct.
(If you answer is option E, then please go to next question; if your selection is not option E, then please jump to question 13).

12. To what extent do you recognize the results from HRA methods?
A. not recognized, B. limited recognized, C. medium recognized, D. mostly recognized, E. completely recognized.

13. Which one do you reckon is more important for petrochemical plants' safety, human error or facility failure?
A. facility failure more important than human error,
B. facility failure is a little more important than human error,
C. human error has equal importance to facility failure,
D. human error is a little more important than facility failure,
E. human error is more important than facility failure.

14. To what extent do you reckon that the Chinese petrochemical industry requires HRA techniques?
A. unnecessary, B. Limited necessary, C. medium necessary, D. necessary, E. very necessary

Fig. 1. The designed questionnaire for this survey.

3 Questionnaire Survey

Due to the 197 participants come from management team and operation team, and they may have different opinions to each question, this study divides them into two groups (one is management team, the other is operation team). We believe that through this division, we can better identify the challenges and opportunities for applying HRA in the Chinese petrochemical plants. The division of the whole sample can be determined by the feedbacks of the question 4 in the questionnaire. Based on the collected data of question 1, question 2 and question 3, the demography information can be identified. The management team contains 36 members (average age 46.1 years old with SD 6.6 years, average working experience 23.8 years with SD 7.7 years). The values of operation team (161 people) are average age 40.8 years old (SD 6.6 years) and average working experience 19.5 years (SD 10.3 years).

3.1 Data Collection

In the questionnaire, question 1 through question 4 are designed for collecting demographic information, and their results have been previously demonstrated, so this section starts from question 5. Based on the designed questionnaire in Fig. 1, we successfully collected 197 feedbacks. According to the replies from the management group and operation group, Table 1 gives the results of question 5 ("do you agree that human error is a key factor to trigger accidents?").

Table 1. The received results of question 5 in each group.

Team	Mostly agree and fully agree	Neutral	Mostly disagree and fully disagree
Management team	91.7% (33 people)	2.8% (1 people)	5.5% (2 people)
Operation team	77.6% (125 people)	13.1% (21 people)	9.3% (15 people)

The question 6 through question 9 are all for checking the frequency level about human error to the occurrence of abnormal scenarios or accidents. The collected feedbacks about these questions are concluded in Table 2.

For the question 10, 11, and 12, they are designed for identifying participants' experience and attitudes in using HRA techniques in petrochemical factories. The received data are summarized as follows.

a) In the management team, there are 29 people (81%) who have experienced some HRA techniques; the data in the operation team is 117 people (72.3%).
b) Among the people who selected yes in question 10, there are only 7 people who can implement a whole HRA process (1 in management group and 6 in operation team).
c) All the participants, who gave their answers to question 12, tend to believe the results from HRA methods.

Question 13 is to survey people's opinion on the importance wight of human error and facility failure when concerning accidents in a petrochemical plant. The received results are displayed in Table 3.

The last question is to investigate people's attitudes on whether the Chinese petrochemical industry requires a specified HRA technique. Table 4 presents their attitudes.

Table 2. The collected feedbacks about the question 6 through question 9.

Question no.	Team	Frequent and very frequent	Sometimes	Seldom and occasionally
6	Management team)	36.1% (13 people)	27.8% (10 people)	36.1% (13 people)
	Operation team	19.2% (31 people)	33% (53 people)	47.8% (77 people)
7	Management team	36.1% (13 people)	33.3% (12 people)	30.6% (11 people)
	Operation team	24.8% (40 people)	25.5% (41 people)	49.7% (80 people)
8	Management team	38.9% (14 people)	36.1% (13 people)	25% (9 people)
	Operation team	23.6% (38 people)	26.1% (42 people)	50.3% (81 people)
9	Management team	39% (14 people)	30.5% (11 people)	30.5% (11 people)
	Operation team	23% (37people)	19.9% (32 people)	57.1% (92 people)

Table 3. The participants' opinion on the weight of human error and facility failure in triggering accidents.

Team	Human error has more weight	Human error and facility failure are equal important	Facility failure has more weight
Management team	36.1% (13 people)	52.8% (19 people)	11.1% (4 people)
Operation team	28.6% (46 people)	54.6% (88 people)	16.8% (27 people)

Table 4. The received opinions on whether HRA is necessary to the Chinese petrochemical industry.

Team	Tend to require HRA	Neutral	Tend to support "unnecessary"
Management team	91.7% (33 people)	0% (0 people)	8.3% (3 people)
Operation team	84.5% (136 people)	4.3% (7 people)	11.2% (18 people)

3.2 Data Analysis

With the collected data, this section presents an analysis. Through learning the data in Table 1, Table 3, Table 4, we find that most participants support HRA and view human error as a significant item. The management group shows more positive attitude to recognize HRA and the importance of human error. Members in management team have ability to make decision, so if they are more welcome to HRA method, it will be better for introducing and applying HRA in Chinese petrochemical plants.

The data in Table 2 reveal that not too many people in both management team and operation team deems that human error is frequently associated with the abnormal scenarios or accidents in petrochemical plants. This result is not match with many widely acknowledged publications which claim about 70% of accidents are related to human error. More importantly, this result may bring challenges to applying HRA technique in the Chinese petrochemical industry, since the people may not think human error is a frequent issue that need to be handled by HRA techniques.

The feedbacks of question 10 through 12 illustrate that although many people have contacted some knowledge on HRA, only limited participants (7 people) can practice a whole HRA practice. This indicates that the HRA experts are insufficient in the petrochemical industry in China.

4 Conclusion

With the designed questionnaire and the 197 participants, we have conducted a study to investigate the challenges and opportunities for applying HRA techniques in the petrochemical industry of China. Through the data collection and data analysis, it can be concluded that there are opportunities for applying HRA technique in the Chinese petrochemical industry.

a) Majority of participants deem that HRA is necessary to this industry.
b) Most participants agree with the opinion that human error is a significant factor in triggering an accident in a petrochemical plant.

Challenges are also living along with opportunities. Through this study, we find that, not too many people working in the petrochemical industry in China thinks human error is frequently associated with abnormal scenarios or accidents. Besides, there is lack of experts who can implement a complete HRA process.

The identified opportunities can guarantee that there are enough people to support applying HRA techniques in the Chinese petrochemical industry. However, the challenges are the barriers to HRA application in the Chinese petrochemical industry. Therefore, with enough HRA supporters, more trainings are required for the people working in the Chinese petrochemical industry to make sure they can understand human error and have ability to use HRA techniques.

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Human Error, Reliability, Resilience, and Performance in Aviation

Is Our Human Factors Capability in Aviation and Maritime Domains Up to the Task?

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Abstract. It is often said by Human Factors professionals that Human Factors needs to be involved in design projects from the start. But how often is this feasible, and how often does it really occur in practice? And, perhaps most importantly, do design and operational organizations have the right people, processes and motivation in place to allow this to happen? As part of a European-funded project called SAFEMODE, which looks at the potential for cross-domain Human Factors learning in aviation and maritime domains, twelve organizations participated in a Human Factors Capability Profiling exercise. This paper gives an anonymized overview of the results, showing the range and differences in HF 'maturity' in the two domains. A key insight is that for both domains, there is a need for further uptake of validated HF methods that can inform design decisions at early design stages.

Keywords: Human factors · Aviation · Maritime · Design · Benchmarking

1 Introduction

Human Performance (HP) is critically important in Aviation and Maritime Transport because both industries are complex and highly interactive, operating in a continually changing environment. To keep these transport 'systems of systems' safe, efficient and effective, adaptation and flexibility are necessary. It is the people in the system that provide this resilience, keeping the traffic moving even when things become difficult, whilst keeping it safe. In simple terms, people create safety. SAFEMODE (Strengthening synergies between Aviation and maritime in the area of human Factors towards achieving more Efficient and resilient MODE of transportation) is a three-year (2019–2022) EU-funded Horizon 2020 project with a consortium of around 30 Partners from aviation, maritime and rail domains, aimed at improving the uptake of Human Factors approaches in the design of aviation and maritime vessels and systems.

Human performance, as a domain, focuses on optimising the human element in complex work systems. It covers all aspects of integrating people – the Human Element

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– into systems, including ensuring for example that there are adequate and competently trained staff, with the right equipment and tools to help them do the job, and managing 'human error', or what is more often referred to these days as performance variability.

Each of these two industrial landscapes has its own key system 'actors': airframe manufacturers and equipment suppliers, airlines, cargo and private planes, airports and air traffic controllers in aviation, for example, and fishing vessels, ferries, cruise-liners and cargo vessels, along with ship designers and builders, ship-owners and companies in maritime. So, the question is, where does the Human Factors effort need to be in each of these complex and interacting landscapes, and specifically in each 'actor' organisation? It is a fact of life that resources are limited, so two questions arise for any organisation:

1. What are the Human Factors relevant to my organisation's activities?
2. What level of Human Factors does my organisation need?

To help organisations answer these questions, we have applied an approach called Human Performance Capability Profiling (HPCP) to specific organisational contexts.

2 The Human Performance Capability Profiling (HPCP) Approach for SAFEMODE

The HPCP borrows heavily from an approach called Human Performance Standard of Excellence (HPSoE)[1] developed in the Air Traffic domain. The approach was created over a period of four years by the ANSP-based group known as EUROCONTROL/FAA Action Plan 15, resulting in a release of a White Paper describing the framework. To enlarge the reach of the approach to a more global ATM audience, in 2016 CANSO (the Civil Air Navigation Services Organisation – a global group of ANSPs), via its Safety Standing Committee (SSC), created a task force to continue the development of the approach, and in 2019 released a second version. The approach developed for SAFEMODE is however based more on the original HPSoE concept, which was more generic in nature.

2.1 HPSoE: Key Concepts

The key concept is that when human performance is managed properly, system performance will increase. Consequently, organisations have to focus on human performance management, not do it ad hoc. The needs behind HPSoE can be summarised as follows:

- Identify which are the key HP areas of focus.
- Identify where an organisation is doing well and where improvements could help business performance.
- Identify what other, similar organisations are doing in this area.

[1] https://www.skybrary.aero/bookshelf/books/3291.pdf.

- Identify the level of maturity an organisation needs to get to, considering the people-centred nature, size and scale of its operations.
- Identify first or next steps to take in managing human performance.

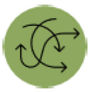
The HPSoE describes the levels of maturity in an objective way for 12 areas of Human Performance. There are four systemic elements – Policy, Strategy and Resources, Leadership, Roles and Responsibilities, and HP Assurance – which indicate that an organisational commitment to HP management is a key issue. The remaining eight elements focus on different operational processes and procedures. The HPSoE is ATM-focused, and SAFEMODE needed to develop something for the wider Aviation system of systems, and also for Maritime domain. Using the same basic framework, the questions have been adapted accordingly in the HPCP.

2.2 The HPCP Framework

The complete HPCP framework consists of 12 elements and is supported by Human Factors techniques and approaches. In the context of SAFEMODE however, which has a design focus, it is important to concentrate on five of these elements specifically. These are ‘core’ to SAFEMODE, which is primarily concerned with Design. The core areas of the framework for this activity are as follows:

POLICY, STRATEGY AND RESOURCES - The degree to which the organisation recognises the importance of people and puts in place policies and resources to actively measure and monitor their human performance. *[Element 1]*

EQUIPMENT AND SUPPORT TOOLS – To ensure that the operational environment including equipment, support tools, and workstations (software and hardware) provide optimal support to job performance. *[Element 3]*



IMPACT OF CHANGE - To ensure the impacts of a change on human performance are identified, assessed, and managed. *[Element 8]*

INVESTIGATION & LEARNING - To identify strengths and weaknesses related to human performance aspects arising from events, incidents and accidents, and to share and implement lessons learnt across the workforce and organisation. *[Element 11]*

HUMAN PERFORMANCE ASSURANCE - To provide assurance that human performance is managed effectively and that HF methods and processes are fit for purpose and focused on reducing risk, optimising human system performance, and realising business benefits. *[Element 12]*

3 The Assessment Process

When performing the assessment, each element is considered one at a time and assessed against five maturity levels:

- Level 1: Initiating
- Level 2: Planning/Initial Implementation
- Level 3: Implementing
- Level 4: Managing & Measuring
- Level 5: Continuous Improvement

Each of these levels contains a series of capability statements describing what must be in place to reach a particular level of maturity for a particular element. For an organisation to be at a specific maturity level, all requirements under lower levels must be met. To support this assessment, justifications and examples of evidence showing how the requirements are met, are also collected.

Once the maturity levels are identified, the next step is to decide if they are sufficient to meet business performance goals or should be higher, and identify any further actions that would help achieve higher levels in the future and / or make the current levels more resilient.

Altogether twelve SAFEMODE Partners conducted their HPCP assessments up to this point. They included representatives from all three sectors: Aviation (5), Maritime (6) and Rail (1), as well as representing different working contexts, both operational and non-operational (e.g., shipping companies and airlines, manufacturers, agencies, regulators, universities and research centres).

4 Results

The results for each Partner are confidential so only group results are presented. The results section is divided into three separate sections – overall maturity levels across all participating organisations, overall results for the two sectors (Aviation and Maritime), and cross-industry insights gained.

4.1 Overall Maturity in Aviation and Maritime

The 3D histogram (see Fig. 1) shows the maturity in the 5 elements and the number of Partners at each level. This ‘city block’ image gives an overall impression of the maturity in these five elements as a whole. The city block can be thought of as ‘where do most organisations live?’, with respect to Human Factors, and the answer is ‘downtown’, with most assessments ending up in the middle. This is not a bad place to be.

Figure 2 presents another view of the same data, showing the results as ‘five towers’, depicting how many organisations currently score at each level of maturity for each of the scales. One way to think of this is, again, where do organisations live: ground floor, mid-level, or top floor penthouse? For example, for Element 1: Policy, Strategy and Resources there are no organisations who are currently at Level 1 (which is good). This is however different to the other four elements, where one or more organisations have yet to start in at least one core Human Factors area.

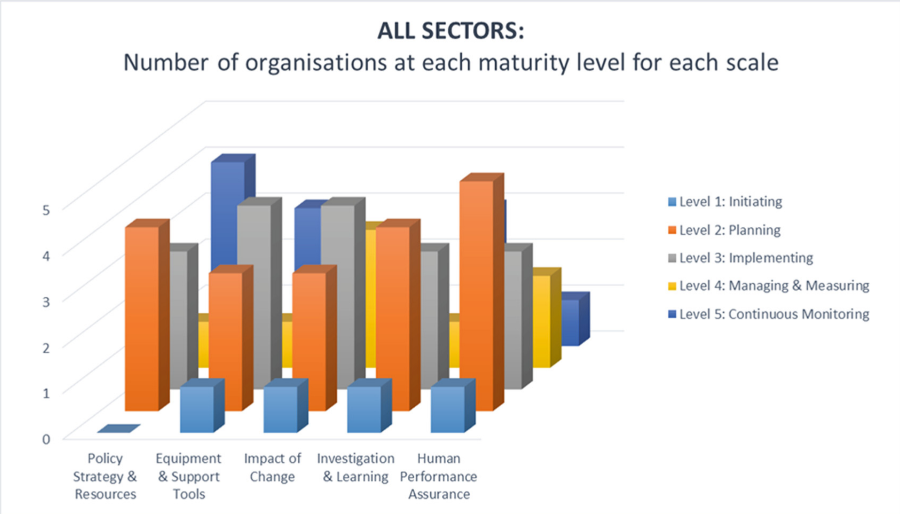


Fig. 1. ‘City Block’ view: HPCP Framework across all 12 organisations

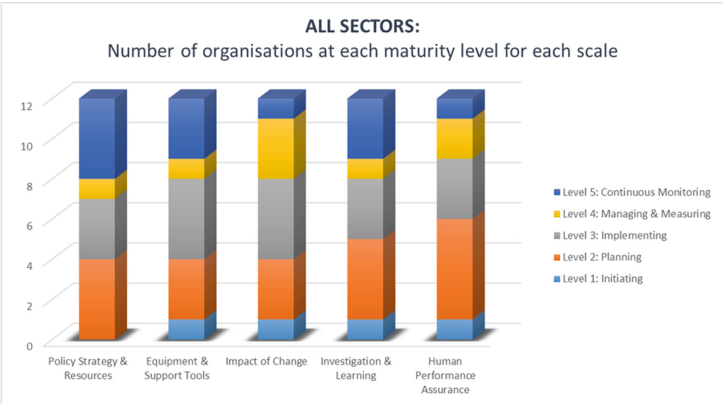


Fig. 2. ‘Five Towers’ view across all 12 organisations

The highest achieved level is for Element 1, Policy and Strategy, and this is encouraging as it shows that a number of organisations are very serious about Human Factors in their business processes and corporate vision. This means that there should be some organisational 'pull' for SAFEMODE inputs, rather than resistance, which suggests that the overall SAFEMODE project is not wasting its time developing products that may 'fall on deaf ears.'

The weakest area overall is Human Performance Assurance (HPA). The low scores on the HPA element suggest that many organisations are not applying formal Human Factors techniques when they address Human Factors issues. This situation could be helped in particular via SAFEMODE's Human Factors Toolkit, and the application of formal methods in SAFEMODE's aviation and maritime case studies.

Overall, 59% of organisations are at level 3 or higher, and this is a reasonably healthy picture. Fully a third (33%) are at Level 2, and this means that these organisations have the correct foundations to consider moving to the next level. This is hopefully something that SAFEMODE can support by showing such organisations how to advance to level 3.

4.2 Aviation

For Aviation, the city block diagram (see Fig. 3) shows that Human Factors is relatively healthy, with a predominance of level 4 and 5. It is also interesting that the organisations canvassed excel in two key elements, policy and design. This is perhaps not so surprising, since there has been so much effort over the years in the areas of cockpit design and controller workstation design, and that there is a fairly strong regulatory backbone reinforcing Human Factors adoption in the industry (especially for cockpits).

The weakest area is Element 5, HPA, which might at first glance seem odd given that there is so much level 5 in Element 2, HF in design. This can be interpreted as follows: Element 2 refers to the practice of getting HF into design, whereas Element 5, at maturity levels 4 & 5, focuses not only on applying HF techniques, but doing so using formal techniques integrated into design processes, and developing better tools.

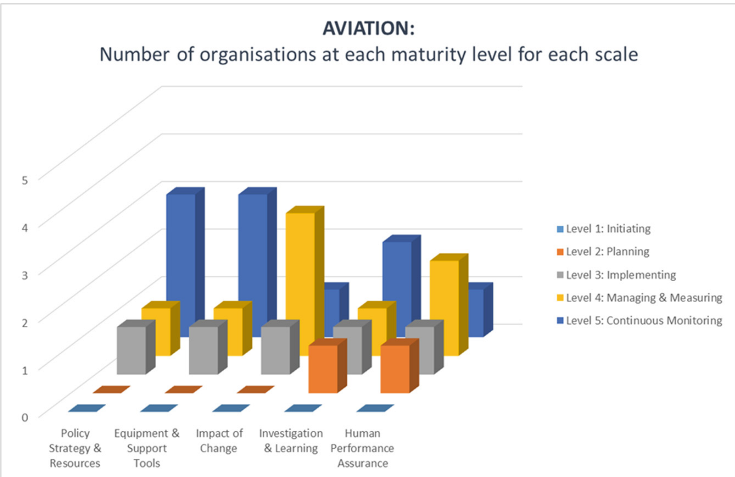


Fig. 3. City Block view for Aviation

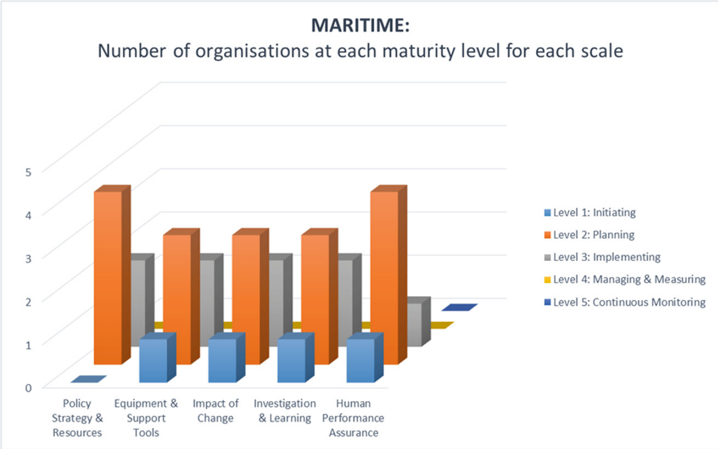


Fig. 4. City Block view for Maritime

4.3 Maritime

For Maritime (Fig. 4), the maturity 'mode' is clearly at Level 2: *Planning*, with some at Level 3: *Implementing*, but none of the Maritime organisations that participated in the HPCP assessment task exercise reached levels 4 or 5. Clearly, this is in contrast with Aviation, and shows that Maritime could indeed benefit from more Human Factors input and expertise.

The strongest element is Policy, Strategy and Resources, which as noted earlier shows a good (indeed necessary) foundation for advancement in Human Factors capability to the Implementing level. The weakest area, as for Aviation, is Element 5, Human Performance Assurance, in this case indicating that there is not much use of formal HF techniques integrated into design processes.

4.4 Cross-Domain Insights from the HPCP Exercise

Maritime could learn from Aviation in terms of the application of Human Factors in design activities, and this is now being pursued within the SAFEMODE project via a set of Aviation and Maritime cases studies where each Partner can see how HF tools are applied, including task analysis, prototyping, use of subjective and psychophysiological tools in real-time simulations, etc.

One interesting observation that has arisen is that for aviation in particular, cockpit design is standardised for particular aircraft types, e.g. a B737 or an A320 etc. This is not at all the case for ship bridge design, where almost all ships have unique bridge designs. This and other 'business model' and 'structural' factors are being further explored within SAFEMODE to see how traditional Human Factors approaches can be adapted to Maritime.

Overall, there are some clear benefits of the HPCP benchmarking approach, already noted by the Partners:

- The HPCP approach gives an aviation or maritime organisation a snapshot of its capability in managing human performance, highlighting where it is strong, and where there may be gaps or needed improvements. Critically, HPCP can help organisations see where to place effort on supporting human performance.
- As more organisations carry out the HPCP exercise in SAFEMODE, this allows them and others to 'benchmark' their own human performance capability against similar companies.
- According to the EUROCONTROL and FAA Action Plan 15, around 70% of total project cost is determined in the first 10% of the project. It is much more cost-effective (60 to 100 times) to change the design of a system in the initial phases of development than to do so once the system has been built and is in operation. HPCP supports human performance implementation early in the design phase and in the change process.
- HPCP provides a unified framework for the assessment and management of Human Factors and human performance. It can enhance safety and human performance communication, ensuring the right professional resources are available in an organisation.
- HPCP helps to determine the current level of human performance, the target level of human performance, and the actions required to improve human performance.

The full details of the HPCP exercise, as well as the case studies and the Human Factors Toolkit arising from the project, will be documented as they occur at the following website: https://safemodeproject.eu/ It is hoped that the information developed by SAFEMODE will be useful for any high risk industry sector, and for Human Factors practitioners and designers in any endeavor where human performance matters.

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Flying High. Voice Stress Analysis to Detect Pre-symptomatic Acute Hypobaric Hypoxia at 25000 Ft

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Abstract. Previous research showed that Acute Hypobaric Hypoxia (AHH) induced pre-symptomatic compensatory voice markers at 20000 ft but not at 25000 ft. These studies were conducted in an intermittent design with pauses in between. Since AHH evolves more rapidly at higher altitudes, compensation might have occurred in theses pauses. Hence, we studied voice reactivity of 16 subjects to AHH at 25000 ft in a hypobaric chamber in a continuous speech design. We analyzed fundamental frequency-range (F0-range) and voice onset time (VOT) in function of the hypoxic symptoms as indicated by the subjects. We did not find the pre-symptomatic compensation (i.e., decreased F0-range and VOT). We found increased F0-range and decreased VOT. We hypothesize that at higher altitudes, voice reactivity to AHH is the output of physiological processes of both compensation and control loss. Voice stress detection is a promising future tool and the role of breathing in regulatory compensation processes should be examined.

Keywords: Acute hypobaric hypoxia · Voice stress analysis · Top-down · Bottom-up · Psychophysiology

1 Introduction

Acute hypobaric hypoxia (AHH) refers to an insufficient oxygen supply caused by a sudden exposure to high altitude without having supplemental oxygen or the protection of cabin pressurization [1]. With increasing altitude, the ambient pressure decreases non-linearly, and with that the atmospheric partial pressure of oxygen (PO_2) along with the time of useful consciousness (TUC) which is the resting time that one remains operational [1]. Although pilots receive a hypoxia symptom recognition training [2,

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3], hypoxia remains a threat due to the combination of cognitive and psychomotor deterioration [4, 5] along with the insidiousness of the phenomenon that hinders clear recognition [1–3]. As an illustration, Pickard and Gradwell [1] compared the hypoxic mindset with that of the alcohol intoxicated driver who is convinced of still mastering his car. Consequently—although the number of hypoxia-caused flight accidents has been divided by factor three between 1976 and 2003 [6]—serious accidents due to acute hypobaric hypoxia still do occur and may moreover often not be recognized as such [5, 6]. Hence, early hypoxia detection, in a pre-symptomatic stage would be desirable.

In a recent study [7], the benefit of voice stress analysis was explored to detect hypoxia in a pre-symptomatic stage based on the presumption of a psychophysiological relationship between stress and the voice output [8, 9]. That is, the voice output shows the attempt of the body to balance bottom-up arousal (sympathetic nervous system) and top-down regulatory activity (parasympathetic nervous system) to compensate for the experienced stressor. According to a recent review [8], the most common voice parameters in hypoxia studies are fundamental frequency related parameters (i.e., the pitch, also called F0) and voice onset time (VOT) [8]. F0 is a phonation-based parameter corresponding with the number of closure-opening cycles of the vocal folds per second (in Hz); VOT is a respiratory-articulation parameter that refers to the time period between the release of a plosive (e.g., ‘p’) and the vocal fold vibration onset of its subsequent vowel [8].

Van Puyvelde et al. [7] reported a different voice reactivity course over time at 20000 ft and 25000 ft and suggested that the impact of AHH on the voice does not obey a linear dose-response curve but shows a non-linear pattern as the one between altitude and ambient pressure. The pre-symptomatic stage at 20000 ft was characterized by a decrease in both F0-range and VOT, in comparison to a sea-level measurement. This voice response was interpreted as an acute top-down regulatory compensation response to hypoxia. However, at 25000 ft, in a pre-symptomatic stage, there was still a decrease in VOT but an increase in F0-range which the authors ascribed mainly to the impact of anticipatory stress at 25000 ft. The study possessed an intermittent design with regular pauses of at least 15s. Hence, possibly these pauses caused false negatives in the detection of the compensatory decrease in F0-range that was observed at 20000 ft due to what is called in physiological signal analysis aliasing or the failure to detect a correct change in a signal due to a too low sampling frequency [9]. From an operational point of view, this is important since the need of continuous cockpit speech to guarantee reliable pre-symptomatic detection would be inefficient. Hence, in the current study, we measured voice reactivity in response to AHH at 25000 ft in a continuous speech design.

2 Method

2.1 Subjects

The study was approved by the Medical Ethics Committee of the University Hospital Brussels (B.U.N. 143201731931) and took place in the hypobaric chamber of the Center for Aerospace Medicine, Military Hospital Queen Astrid, Brussels, Belgium. Sixteen male adults with a military ‘Very High Altitude’ training including hypobaric hypoxia training participated (mean age, $M = 35.6$; $SD = 8.3$).

2.2 Materials

Voice recording occurred with a Shure Beta 58A Microphone (Shure, UK) and Interface Focusrite Scarlett 2i2 (© Focusrite Audio Engineering Plc.) at a sampling frequency of 44100 Hz in Ableton Live, v.9 (Ableton Inc., Colorado, USA). We used a standardized speech set of two-syllable nonsense words [7]. Speech analyses were performed in Matlab and PRAAT [11], statistical analyses in SPSS (v.25.0).

2.3 Procedure

After briefing and signing an informed consent, a baseline speech test at sea-level (SL) was recorded. Subsequently, after 30 min of pre-breathing 100% oxygen to prevent decompression sickness, the same speech test was performed at 25000 ft. During the test, the participants indicated when and which symptoms they felt. The bottom value of 65% SpO2 was set to break off the experiment and put on the mask, however the participants could put on their mask earlier if wanted.

2.4 Speech Analysis

The final analyses were based on 15 recordings (one missing value). The speech samples were prepared for automatic pre-segmentation in Matlab by manually removing noise and reading errors ($<3\%$). The audio signal was automatically pre-segmented using a custom program written in Matlab. A syllable was considered present if the running average (over 100 samples) of the amplitude was larger than a fraction (5%) of the maximum average amplitude. For each segmented syllable F0 was computed with the 'pitch' routine of Matlab with default parameters, except for a window length equal to 52 ms, an overlap between the windows of half the window length and a median filter length of 7. An estimate of the F0 was thus obtained for each window position and the average of the F0 over the entire syllable was computed. The F0-range was the difference between the F0 values of syllable 1 and 2 based on a logarithmic scale log10(F0) to assign frequencies [7]. For VOT, previous research showed that the consonant 'p' is sensitive for fatigue-related stressors due to the larger average air flow required to pronounce it [12]. Therefore, we analyzed VOT of the 'p-words' using PRAAT [11] with plosive onset values based on the pre-segmentation calculated by MatLab and VOT based on second zero-crossing of the glottal pulse [7].

2.5 Statistical Analysis

The data were analyzed in function of the indicated symptoms. Mean F0-range of each word and VOT for the p-words[9,26] were calculated for the sea-level period (SL), the pre-symptomatic period at altitude (S0), the period with one reported symptom (S1), two symptoms (S2), three symptoms (S3), $\geq$ symptoms ($S \geq 4$). We used linear mixed models with the symptom level (SL, S0, S1, S2, S3, $S \geq 4$) as independent repeated measure variable treated as fixed effect, the different voice test trials nested within the participants treated as random effect; and F0-range and VOT as dependent variables. An alpha-level of .05 was used and extra post hoc pairwise comparisons were performed adjusted with Bonferroni correction.

3 Results

There was a significant effect of the symptom level on the log10(F0-range), $F(5, 250.870) = 36.948$, $p < .001$. Log10(F0-range) significantly increased from SL ($M = 0.0371$; $SD = 0.0149$) to S0 ($M = 0.0453$; $SD = 0.0232$), $p < .001$. Subsequently, there was a plateau, showing no significant difference from S0 to S1 ($M = 0.0501$; $SD = 0.0210$), $p = .802$, from S1 to S2 ($M = 0.0684$; $SD = 0.0364$), $p = .114$ and from S2 to S3 ($M = 0.0662$ $SD = 0.0413$), $p = 1.000$. From S3 to S $\geq$ 4 ($M = 0.0973$; $SD = 0.0244$), $p < .001$, the log10(F0-range) again increased significantly, all Bonferroni corrected. The log10(F0-range) at SL was significantly smaller than at any other symptom level, $p < .001$, Bonferroni corrected (see Fig. 1).

There was a significant effect of the symptom level on VOT, $F(5, 366.807) = 34.166$, $p < .001$. VOT significantly decreased from SL ($M = 0.0150$; $SD = 0.0009$) to S0 ($M = 0.0126$; $SD = 0.0008$), $p < .001$. Then there was a plateau with no significant difference, neither from S0 to S1 ($M = 0.0122$; $SD = 0.0008$), $p = .155$, nor from S1 to S2 ($M = 0.0124$; $SD = 0.0008$), $p = 1.000$. Then there was a significant increase from S2 to S3 ($M = 0.0134$; $SD = 0.0009$), $p = .005$. The further increase from S3 to S $\geq$ 4 ($M = 0.0147$; $SD = 0.0014$), was not significant, $p = .251$. VOT at SL was significantly larger than any other symptom level, $p < .001$, Bonferroni corrected, except at S $\geq$ 4, $p = .1000$ (see Fig. 1).

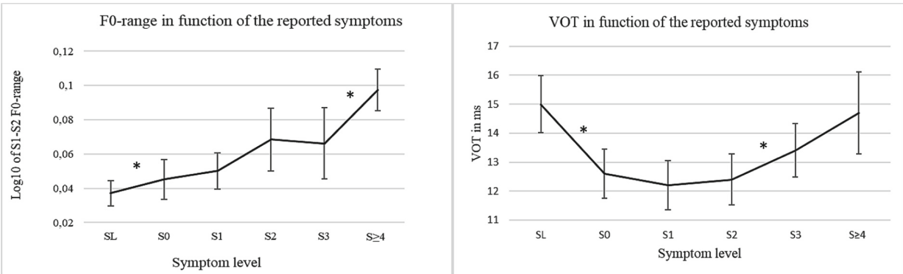

Fig. 1. The voice reactivity in the parameters Log10(F0-range) and VOT (in ms) during the different symptom levels. Significant changes are indicated by an asterisk*.

4 Discussion

In the current study we examined the voice output of 16 subjects at 25000 ft altitude in a hypobaric chamber using a continuous speech design with a standardized two-syllable nonsense test. We analyzed F0-range and VOT in function of the symptoms as indicated by the subjects (i.e., SL, S0, S1, S2, S3, S $\geq$ 4). A continuous speech design was chosen to examine the incidence of a pre-symptomatic compensatory mechanism and to exclude aliasing as a reason in case this compensation was not found.

In correspondence with Van Puyvelde et al. [7], we did not find the pre-symptomatic compensatory mechanism characterized by a combined decrease F0-range and VOT at 25000 ft during S0. We also observed a significant decrease in VOT whereas F0-range significantly increased. Hence the apparent absence of a top-down compensation at 25000 ft is not due to aliasing. From an operational point of view, this may be both beneficial and adverse. As said before, it would be impossible to ask pilots to maintain continuous speech in a cockpit during a flight. However, this result also implies that different psychophysiological mechanisms seems to be at work dependent from the altitude which complicates AHH detection.

According to the Model of Voice Effort (MOVE) [8], decreases in F0-range as well as VOT reflect ongoing top-down compensation mechanisms whereas an increase in those parameters reflects the commencement of control loss. Hence, according to this theory, when top-down control is dominating, the F0-range and VOT would decrease whereas when loss of control starts to dominate, the F0-range and VOT would increase. Therefore Van Puyvelde et al. [7] interpreted the combined decrease of VOT and F0-range at 20000 ft during the pre-symptomatic phase as one compensatory voice response. We argue that it is however important to consider both voice parameters separately and to take into account that VOT and F0-range may have different response time curves as well as different dose-response curves. This is not unobvious since, anatomically, both voice parameters are acting at a different voice level as well. F0-range is the expression of activity in the laryngeal nerves and cricothyroid muscle system which causes vocal fold contraction or relaxation whereas VOT is related to the articulatory co-ordinational part of the respiration system [8, 9]. Hence, we propose that both voice parameters are simultaneously at work driven by different underpinnings, being phonation (F0-range) and respiration (VOT).

Concretely, in the results, we suggest that the increased F0-range from SL to S0 at 25000 ft was the expression of sympathetic arousal due to the first impact of the acute hypoxia. F0 has indeed been shown to be sensitive for acute arousal in particular, characterized by increases in both F0 and F0-range (e.g., real-life emergency, see review [8]). On the other hand, the simultaneous decrease in VOT is proposed to be the expression of parasympathetic top-down regulation in the respiratory system. In the literature it has been accepted that the respiration is the main key for regulation of autonomic stress reactivity [2, 8–10, 13]. Respiration has a parasympathetic regulation on sympathetic bottom-up arousal via the mediation of the nervus vagus on the sinoatrial node of the heart to inhibit bottom-up arousal [8, 9]. As already mentioned, VOT is part of the respiratory component of voice processing. The regularity of breathing and the extent to which expiration is preserved, is related with the coordination of timing between vowels and consonants [8]. Similar as during physical exercise, hypoxia is likely to evoke a competition for resources between the ventilation processes of speech and the metabolic demands of the hypoxic conditions [8, 14], hence inducing immediate top-down regulation. This is for instance one of the reasons why the consonant ‘p’ that requires a larger average air flow is sensitive for fatigue [12].

After this first attempt to regulate, we suggest that the plateau in the F0-range from S0 to S3 was the indirect and therefore delayed response of the laryngeal system to this previous respiration-induced attempt for regulation. The laryngeal system is indirectly related to the respiration system since the cricothyroid muscle that is involved in vocal fold stretching and thus F0 regulation is also mediated by the nervus vagus whose parasympathetic output is induced by respiration [8, 9]. Later in the VOT-course, when the participants indicated their second and third symptom (from S2 to S3) there was a significant increase in VOT from S2 to S3. We suggest that this re-increase of VOT was the result of the first loss of top-down control. Notable, this loss of control in VOT was again pursued in a delayed manner by the first new significant increase in F0-range at S3 after the plateau in the previous stages. Hence, a new release of bottom-up arousal after the parasympathetic brake is starting to break down.

Overall, we propose that the voice output has different parameters that give together insight in the final balance between compensation and control of ongoing sympathetic and parasympathetic processes that can be active at the same time. Support for this hypothesis can be found in the model of Berntson, Cacioppo and Quigley [15]. This model shows that on the level of the autonomic nervous system, stress-reactivity is the final integrated outcome of ongoing sympathetic arousal and/or parasympathetic regulation processes. The sympathetic and parasympathetic component can occur in activation/co-inhibition (i.e., they simultaneously increase or decrease), in reciprocity (i.e., one increases whereas the other decreases) or independent from one another (i.e., either sympathetic or parasympathetic). Since voice reactivity is the output of similar psychophysiological processes and their underpinning autonomic fluctuations in the sympathetic and parasympathetic nervous system, the voice may show similar dynamic processes [8].

This new hypothesis may also explain as to why the F0-range in Van Puyvelde et al. [8] decreased (and not increased) in the pre-symptomatic stage at 20000 ft is probably due to the difference in altitude. AHH is a non-linear process and so is its impact. The hypoxic induction and its impact are slower at lower altitudes than at the higher 25000 ft, which allows subjects to adapt and prepare more gradually and to have a more efficacious control from the start. This may explain as to why chronic hypoxia to which persons can gradually adapt at high altitudes shows a maintained VOT-decrease [16].

The increase in VOT from S2 to S3 corresponds with the significant increase in VOT at a symptomatic stage in Saito et al. [17]. However, Saito et al. [8] did not find a first attempt to control in the start of their experiment which may be explained by the difference in instructions in our experiment and the background of the subjects. The subjects in the current study were trained in symptom recognition, they were prepared to become hypoxic and from their training experience they knew on average when to expect the first symptoms. Consequently, there was an inevitable focus on symptom recognition and increased motivation to compensate which was not the case in Saito et al. [8]. Hence it would be interesting to replicate the experiment in a single blinded crossover study with a real altitude and placebo condition. For instance, Benedetti and Piedimonte [18] proposed a placebo effect conditioned by the ritual inherent of the experiment or training that only can be avoided by putting the participant in a "not-knowing" position.

In summary, based on the current voice analyses at an altitude of 25000 ft in a hypobaric chamber, we presented a hypothesis that voice reactivity in response to AHH is the output of a trade-off between ongoing mechanisms of both compensation and control loss but that different voice parameters obey different time-lines and dose-response curves. We suggest that VOT responded immediately to top-down control after acute exposure to altitude due to its direct respiratory link and that F0-range responded in a delayed manner innerved by the nervus vagus. Hence, we hypothesize that VOT may express the acute attempt of the body to take control over the situation being the result of parasympathetic respiration-driven regulation whereas F0-range may be considered as the output of the success of that attempt showing the level of ongoing sympathetic arousal. We believe that voice stress analysis is a promising tool to further explore with the goal to facilitate future real-time voice detection. However, there is still a bulk of work to do to further disentangle the different response curves of different voice parameters and the impact of other ongoing stress processes on top of the acute hypoxia-induced phasic stress response [7]. Moreover, it is not yet clear whether pilots will respond similar in real-life flying conditions when not expecting to become hypoxic and being involved in other tasks than when they are involved only in a hypobaric training experiment. Finally, detailed and varied respiration parameters should be measured (e.g., amplitude, ventilation, flow of inhalation and exhalation, frequency) in future AHH research to test the hypothesis that respiratory based processes drive the observed changes in the voice output. As previously suggested by Van Puyvelde et al., since respiration is the driving force of both stress and speech, it may be the missing link to fully understand voice stress.

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Human Factors Analysis for a New Wake Vortex Air Traffic Alert

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Abstract. Humans play an essential role in air transport safety. Yet the integration of Human Factors into design is not systematically comprehensive nor uniform. A Horizon Europe 2020 research project called SAFEMODE, aims to consolidate a HUman Risk-Informed Design (HURID) framework. Rather than take a piecemeal approach, focusing on either Human Factors, learning from incidents, or risk modelling, SAFEMODE integrates all of these into one framework for designers to use, whether developing improvements or new systems, and at varying stages of design from the early concept stage, to detailed design prior to deployment. One of the selected Case Studies supporting HURID validation is the design of a new Wake Vortex Air Traffic Alert for Cruise phase of flight. The paper presents the HURID application in support of the concept design.

Keywords: Human Factors · Wake vortex · Upset prevention

1 Introduction

The development of new operational concepts needs to adequately integrate Human Factors (HF), ensuring that the expected human performance meets human capabilities. Several Human Factors methodologies and techniques have been developed over time, with specific added values, for use at various steps of the concept development lifecycle.

The European Organisation for the Safety of Air Navigation (EUROCONTROL), is collaborating in a Horizon Europe 2020 research project called SAFEMODE, aimed at consolidating a HUman Risk-Informed Design (HURID) framework. Rather than take a piecemeal approach, focusing on either Human Factors, learning from incidents, or risk modelling, SAFEMODE integrates all of these into one framework for designers: whether developing improvements or new systems, and at varying stages of design (from the early concept stage, to detailed design prior to deployment). SAFEMODE does this by developing each function separately, then bringing them together, proposing a flexible and scalable approach for different stages of the design life cycle – covering concept definition, design and validation, and resource availability. SAFEMODE also seeks cross-fertilisation of the approach to human factors between different transport

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modes, and gathers a consortium of Partners from the maritime and aviation domains. In view of validating HURID, the project relies on a series of case studies from both aviation and maritime domains. This paper presents the HURID framework and its application in support of the wake alert concept design, and describes the human factors analysis approach to support an appropriate level of human performance assurance.

2 HUman Risk-Informed Design (HURID) Framework

HURID is a simple learning cycle: operate and maintain a system, capture data on system performance for learning, and then apply it together with Human Factors (HF) expertise and techniques to deliver an improved, risk-informed design. HURID is supported by a series of HF activities which cover the concept development lifecycle. It includes incident analysis and Human Factors data exploitation, selection of appropriate HF techniques from an HF methodology toolkit, analysis of Human Factors with the involvement of actors (end-users as operational experts, concept expert, Human Factors experts, safety experts), simulations (from low fidelity to high fidelity) and risk modelling, as illustrated in Fig. 1.

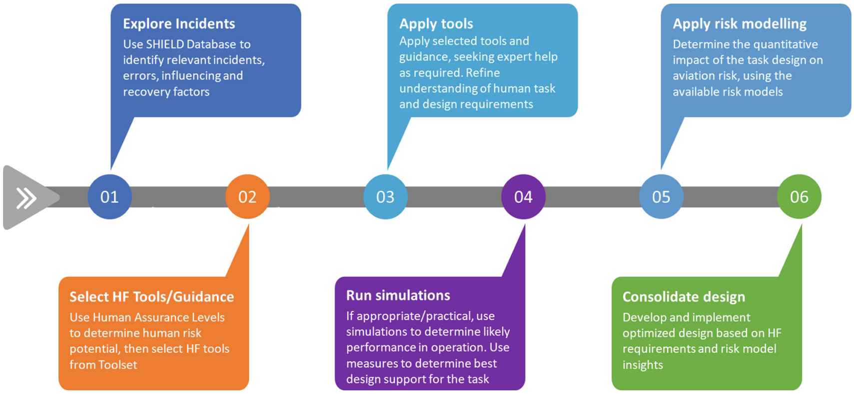

Fig. 1. Main steps of Human Risk-Informed Design (HURID) framework

SAFEMODE project case study goals are to support the validation of the HURID method by applying the HURID process to the development of new operational concepts, and by demonstrating that the HF design elements are adequately taken into account to ensure acceptable human performance when operating the new concepts. One of the aviation case studies is developing a new operational concept, aimed at facilitating the safe management by human in control, (i.e. Flight Crews) of wake turbulence encounter upsets in flight [1].

3 Wake Turbulence Aviation Risk

Every lift-generating, hence flying, aircraft trails wake vortices. The trailing vortices roll-up into a pair of coherent, counter-rotating vortices that can persist for several minutes after the wake-generating aircraft has flown by, potentially causing a hazard to any following aircraft that may encounter these vortices, resulting in an aircraft upset (induced roll, loss of height or rate of climb), potential loss of control in-flight (LOC-I) and cabin injuries.

Despite maintaining the correct traffic separation according to the applicable rules, wake turbulence encounters are being occasionally reported in the En-route/cruise phase of flight in some airspace. Some of these events have resulted in significant upsets (reaching up to 60° bank), in particular for smaller aircraft types such as business jets. Experience has demonstrated that if the pilot reacts at the first roll motion – possibly influenced by the startle effect - when in the core of the vortex, the roll motion could be potentially amplified by this initial piloting action, due to the lack of anticipation. Moreover, En-route Air Traffic Control has no specific means to detect wake encounter risk. Wake detection and avoidance is clearly not a priority task compared to the essential duty of controlled air traffic collision prevention.

4 Wake Alerting Concept

A tactical wake turbulence risk alerting the Flight Crews ahead of the encounter could therefore be beneficial to reduce the startle effect and support appropriate management of these conflicts. The envisaged risk-alerting logic relies on a ground-based predictor, connected to the Air Traffic Control system, using information from air traffic surveillance and meteorological conditions in upper airspace, as well as a wake behaviour evolution and encounter model. The wake turbulence encounter alert function is displayed to the En-route/Area Control Centre (ACC) to both Executive & Planning Air Traffic Controllers (ATCOs). This alert will be calculated and displayed at a time horizon of 2–3 min before the predicted wake upset. Once the ATCO receives this WAKE alert, the Executive Controller will have to inform the flight Crew of the exposed aircraft, via voice communication, at the earliest opportunity, as illustrated in Fig. 2. Since the primary goal for Loss of Control Inflight (LOC-I) risk mitigation is to inform the flight crew of the imminent wake encounter risk, the wake alert is sought to be classified as a 'Caution' type of Alert: for conditions that require immediate flight crew awareness and *subsequent* flight crew response. The 'Caution' information will be accompanied by Traffic Information about the Generating aircraft, so that the flight crew know where the threat is coming from. For flight crews, the Caution Wake Turbulence information will necessitate a decision-making process on the subsequent actions to take: either decide for a trajectory adaptation for wake upset prevention, or secure the cabin and proceed with the planned trajectory, with the Pilot Flying (PF) covering the controls and managing the possible upset in accordance with Standard Operating Procedures (SOPs), Flight Manual and Training. As a complementary design option for the new ATC procedure related to the wake caution alert, the Planner & Executive Controllers may also evaluate the feasibility to resolve the wake conflict by adapting the flight trajectories and crossing geometry, taking into account the wake conflict geometry, e.g. avoiding the crossing with the aircraft descending in front, while not creating other traffic conflicts due to this manoeuvre.

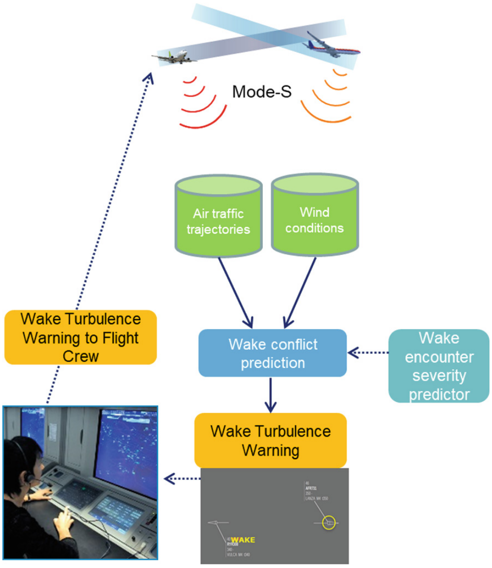

Fig. 2. Air Traffic Control Wake Turbulence Alerting concept

5 HF Analysis

Regarding the design intent and the concept's novelty, the first overriding question to be answered is whether this is a relatively straightforward addition to the existing design and the current operational working practices, or a departure from their normal way of working.

The HF analysis methodology is selected from the HURID HF toolkit. Considering the nature of the concept, addressing Air Traffic Management and its maturity, the Single European Sky Air traffic management Research (SESAR) Human Performance (HP) Case Methodology, presented in the SESAR HP presentation guide [3], is used as a guiding reference for the HF assessment. The SESAR HP method provides a structured and argument-based approach to assess HF-related risk and their mitigation, addressing roles and responsibilities, human and system interactions, teams and communications, and transition to the new operations (including training). Applying the HURID process, the concept design is supported by:

- understanding the HF issues to be addressed, supported by incident analysis
- assessing the impact of the new concepts on human performance, identifying the HF areas affected by the change
- providing human performance assurance of the proposed design based on validations involving airline pilots and ATCOs.

5.1 Analysing the Human Factors in Wake Turbulence Occurrences

The analysis of wake turbulence encounter reports over a 2 year period (2017–2018) (shared by two of the SAFEMODE Aircraft Operator Partners), from a Human Factors perspective confirmed that in almost all cases (90%), the Flight Crews were unable to anticipate the events. The statistics are detailed in Fig. 3.

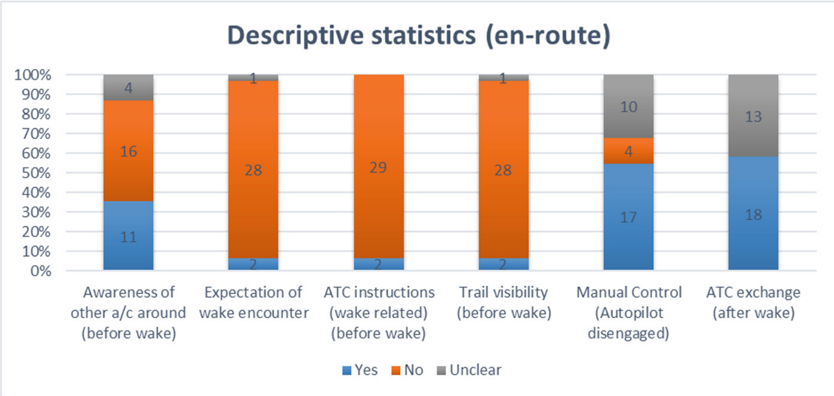

Fig. 3. Statistics of human factors involved related to anticipation and detection of reported wake turbulence encounters in cruise phase of flight

5.2 Task Analysis

The initial HF assessment starts with an understanding of the baseline operating methods, focusing on the role and actions of the human and interactions with the system and operational environment. Hierarchical Task Analysis (HTA) can support this understanding, as well as how the operating method needs to change. In the case of the En-route wake alert, both airborne side with Flight Crews and ground-based side with Air Traffic Controllers need to be assessed. The task analysis for Flight Crew management of wake turbulence encounter in cruise is developed hereafter.

In cruise, flights are typically managed by auto-pilot automated functions and the Flight Management System (FMS): the flight crew have primarily a flight monitoring role, executing the ATC instructions, and evaluating strategies for optimising flight performance. The flight crew comprises two roles: the Pilot Flying (PF) and the Monitoring (PM). The Pilot Flying is mainly responsible for flight execution and navigation, and compliance with ATC instructions, while the Pilot Monitoring is responsible for ATC communications and the monitoring and checking of actions by the PF. The Flight Crews are supported by multiple aircraft and flight management systems and displays, including the primary flight display (PFD) and the navigation display (ND). The management of a wake turbulence encounter has been assessed by describing the actions taken before, during and after the wake encounter, considering the flight crew, their use of visual information out-the-window and from instrumentation, the effect of automation, their control actions as well as the communication with Air Traffic Control. The resulting merged task analysis is shown in a consolidated table representation in Table 1.

Table 1. Merged task analysis of wake turbulence encounter management by Flight Crews in cruise phase of flight.

Time	Pilot Flying (PF)	Pilot Not Flying (PNF)	Outside View	Cockpit instrumentation	A/c & autopilot status	Action / Control	ATC
Pre-wake	Expect smooth flight path A/P engaged If expected WVE, cover controls in case Potential briefing PF/PNF	If time available, inform Cabin Crew Monitor flight path evolution Active monitoring Put seat belt sign ON if time allows	Other aircraft awareness Monitoring other aircraft trajectory Check collision course Depends on day/night (IMC) conditions	Check attitude, altitude, speed, Bank angle (in turn) TCAS use for getting relative trajectory (not permanent/for every traffic proximity)	Check A/P status Keep A/P engaged even if potential WVE expected	Monitor expected behaviour and detect unsual situations Plan for manual intervention Adapt seat position to be hands-on	if risk suspected - Go for lateral offset - Ask for trajectory change (heading / level)
Wake hits	See how A/P cope and correct attitude and re-establish flight path ANC golden rule (Aviate, Navigate, Communicate)	See if agreement in the PF actions (if sitting in the cockpit at that time) Put seat belt sign ON if time allows	At that time focus on instruments	PF checks primary flight/ attitude parameters PM will check flight path	Depends if A/P automatically or manually disengaged Check FMA (flight mode annunciation) for normal/degraded mode	Cf. PF	No time for ATC com
A/C Stabilised	Check everything back to nominal Discussion between PF/PM	Same as PF		Check everything back to nominal	Re-engage A/P if needed	check with CC then PA for explaining/re-assuring	Report to ATC , inquire about generating traffic and file ASR

5.3 HMI Design

The new wake alert information will need to be presented to the Air Traffic Controller on their surveillance display HMI. An initial HMI design is defined, building on the following key principles:

- Once the risk of a significant wake encounter is predicted for a given traffic, it displays a simple 'WAKE' text in the flight label of the affected aircraft.
- the alert is classified as a caution, and is therefore displayed with a yellow colour, as per EASA NPA on AMC 25.1322: Flight Crew Alerting [4].
- the affected traffic is identified, as well as the wake generating traffic in order to facilitate the 'traffic information' message from the ATCO to the Pilots
- the information shall not clutter or hide other information and shall meet best practice of HMI design HF principles.

6 Human Assurance Validations

Using the new wake alerting concept and preliminary design, the HURID application will extend into validation objectives, aiming at providing human performance assurance on adequate adaptation of roles & responsibilities, appropriate design and execution of new operating methods/tasks, appropriate new HMI, appropriate communication/phraseology, appropriate skills and appropriate training (scenario, method/technique, objectives).

The validation encompasses several complementary activities involving end-users: HMI design reviews, Hazard & Operability (HAZOP) sessions, and real-time human-in-the-loop real-time air traffic control and cockpit flight simulations [2].

The HMI design review is to be based on HMI design Guidance. Referenced guides and checklists from SAFEMODE Human Assurance Toolkit, such as SESAR HP Guidance [3] or HMI design checklist from Federal Aviation Administration, will be used for evaluating whether the right information is being presented in the right format based on user feedback.

Error identification techniques such as TRACER, HAZOP and STAMP determine what can go wrong and how the human actors can respond to system disturbances and events, or degraded conditions, in a resilient fashion, as well as determining what errors could occur and how these could be recovered or their consequences mitigated. A HAZOP session will gather both Controllers and Pilots, in order to ensure the best input from expert users, and ensure capture of best practices of crew collaboration during wake events.

The validation also relies on high-fidelity simulations, involving licensed controllers and flight crews in realistic and representative conditions. HP measurements will include workload, situation awareness, trust, reaction-time, error, etc., as well as using more objective psychophysiological measures such as eye tracking and Electrodermal Activity (EDA). In particular, the eye-tracking is expected to support the refined determination of the sequence of actions before and after detection and reaction to the En-route ATC Wake alert, and understand further the Controller decision-making process when prioritising these tasks by determining which information he/she is looking at. To complement the validation, a Cockpit Flight Simulation will provide means to evaluate the performance of the Flight Crews to prepare for, manage or avoid wake encounter upset with the new ATC wake alerting information, and resulting safety benefits. More specifically, the validation will address the feasibility and acceptability of the Flight Crew procedure/actions, the improvement in the wake upset management as well as the training scenarios and their effectiveness. The validation will be supported by analysis of objective measurements to characterise pilot performance and decision-making (simulator flight behaviour/parameter recording and analysis, complemented by expert observation) and by subjective measurements (to capture the Pilot feedback).

As part of HURID (Fig. 1), risk models are used to describe the risk chain from accident precursors to accident, identifying preventive & protective (recovery) barriers and influence layers with their respective system-based and human (factor) deficiency contributions, using a fault-tree graphical representation. A wake turbulence risk model for cruise phase of flight has been developed, representing the chain of events from initial airborne wake generated conflict to loss of control in-flight and the ‘barriers’ including conflict prevention, detection, avoidance and upset recovery, with their related causes of inefficiencies at Human (Flight Crews and Air Traffic Controllers), procedural and system levels. Using incident reporting statistics and validation results, an initial qualitative assessment of the new wake alerting concept will be undertaken to determermine whether it will improve several protection layers: significantly reducing the likelihood of inefficient wake turbulence encounter risk detection and avoidance, reducing the likelihood of inefficient Pilot upset recovery actions, and ultimately reducing the likelihood of loss of control in-flight (LOC-I) and passengers (severe) injuries due to a wake turbulence encounter. Furthermore a possible quantification of benefits in terms of (orders of magnitude of) likelihood reduction is based on the outcome of the validation activities, including real-time simulation results. Eventually, the use of a risk model consolidates the understanding on the safety benefits of the new proposed concept, and the level of enhanced mitigation of human errors or inefficiencies in the risk chain, which are contributing to operational incidents and accidents.

7 Conclusions

This paper has introduced HURID as a consolidated approach to address Human Factors in risk-based design, gathering in a single framework a set of complementary activities covering the concept development lifecycle, from human factors issue identification, to human factor analysis of proposed concept and validation supporting human performance assurance. It has also illustrated the application of HURID to a case study on the design of a new wake alerting to Air Traffic Controllers in view of cautionary informing the Flight Crews of the risk of predicted imminent wake turbulence encounter in order for them to avoid the startle effect in managing the upset, or if possible implement wake avoidance strategies. The Human Factors analysis involved end-users at every step of the design assessment, from understanding the operations (via incident analysis and hierarchical task analysis), to refining the design (design reviews, hazard identification), and training and validation (real-time simulation).

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Organizational Effects on Human Performance

How Many Human Factors Influenced the June 30, 2013, Yarnell Hill Fire 19 Fatalities and Yet Were Never Investigated Nor Documented?

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Abstract. Wildland firefighting is inherently dangerous, fraught with simple mishaps to inevitable fatal outcomes for the unwary. Established, sound rules and guidelines will continue to work to keep Wildland Firefighters and Firefighters safe. Human factors, consistent across all work groups, are variously broken down into human errors, human failures, error chain(s), etc. making fatalities unavoidable. All we can do is reduce them. Nineteen Prescott FD Granite Mountain Hot Shot wildland firefighters and supervisors perished on the June 2013 Yarnell Hill Fire in Arizona. Inexplicably, they left their Safety Zone during explosive fire behavior. A Serious Accident Investigation Team found, "… no indication of negligence, reckless actions, or violations of policy or protocol." The authors and others infer: the final, fatal link, in a long chain of bad decisions with good outcomes. Among other things, tunnel vision, auditory exclusion, goal fixation, non-critical thinking, destructive goal pursuit, Groupthink, and "Friendly Fire" are discussed.

Keywords: Yarnell Hill Fire · Wildland firefighting · Friendly fire · Human factors

1 Introduction

How is it possible that 19 wildland firefighters perished on the Arizona State Forestry (ASF) Yarnell Hill (YH) Fire in one fell swoop, yet the *USFS federally-funded* Serious Accident Investigation Team and Report (SAIT-SAIR) boldly and unbelievably concluded that they found "… ***no indication of negligence, reckless actions, or violations of policy or protocol***"? (emphasis added) [1–3]. Additionally, "3. The Team recommends … develop[ing] a ***wildland fire staff ride*** for the Yarnell Hill Fire incident. The staff ride is a process of conveying the lessons learned from this incident for future fire leaders." Furthermore, "5. The Team recommends that the State of Arizona request the NWCG and/or Wildland Fire Leadership Council (WFLC) to **charter a team of interagency**

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wildland fire and *human factors* experts to conduct further analysis of this event and the wildland fire communications environment." (emphasis added) [1–3].

Human factors refer to environmental, organizational and job factors, and human and individual characteristics, which influence behavior at work in a way which can positively or adversely affect safety [5]. The Staff Ride is a stellar idea, brought to fruition more from a mandated court order than from this SAIT recommendation [4]. However, it's been reported that the "*official*" ones were fairly restrictive and required to use and follow the "*official*" SAIR, thus impeding any valid lessons learned [4]. And the interagency team of "*human factors experts*"? Likely discussed but certainly never taken on to completion. And so, the authors and others (e.g. InvestigativeMEDIA, Yarnell Hill Fire Revelations) took it upon themselves to accept and attend to this crucial task [4].

There will always be a continuing need for dedicated research on the Yarnell Hill (YH) Fire fatalities, seeking out and gathering newly revealed public records evidence regarding the causal human factors and human errors ignored in the alleged "investigation." Some WFs, FFs, and slightly inquisitive others are still unsure whether there was a rogue firing (burning out) operation in the Sesame Street and Shrine Fuel-Fire Break Corridor. This is informally referred to in the insensitively-named Serious Accident Investigation Team "Factual and Management Report" (SAIT-SAIR) as the "the two-track road (an old fuel break) between Sesame Street and Shrine Road … preparing for burnout along the dozer line." [3]. Some GMHS family, friends, and loved ones, are grudgingly aware of it, and prefer to euphemistically (and incorrectly) refer to it as a "back burn." [4] (i.e. *"I stand firm that there was a back burn that came up that canyon. It was this fact along with the weather change that the IC never sent out because they were busy evacuating that caused the death of Granite Mountain.")* [4]. This is a wishful yet out-of-place sentiment. Allegedly "*evacuating*" had nothing to do with their deaths! Undeniably, from their viable Safety Zone in the black, they had the best vantage point of anyone on the fire (except Air Attack), of the increasingly adverse weather and the resultant aggressive fire behavior that deceived them. The GMHS veterans knew better!

Because of all this, WFs, FFs, and others will continue to struggle to make sense of the June 30, 2013, YH Fire; the "*how and why*" 19 of the 20 Granite Mountain Hot Shot (GMHS) fatalities. We all certainly know *how* they died. However, there is a rightful need to analyze *why* so many died needlessly and *why* key evidence is concealed, impeding lessons learned; all the while restricting YH Fire-informed and -knowledgeable USFS employees from talking about or legally being questioned for the tragedy [4].

1.1 Background

The magnitude and complexity of the fire itself and of the human response to it will vary because fire operations are inherently dangerous and will never change [6]. The risk to wildland firefighters (WFs) and Firefighters (FFs) has increased in recent years largely due to large fires have been reported in the Wildland Urban Interface (WUI); "where structures and other human development meet or intermingle with wildland or vegetative fuels." [7]. Was there a rogue firing operation below them in the Sesame Street and Shrine Fuel-Fire Break Corridor areas that they were unaware of because they had no lookout or failed to notify Air Attack? Or because those involved with the several firing operations never informed anyone? Likely all of them. This was a

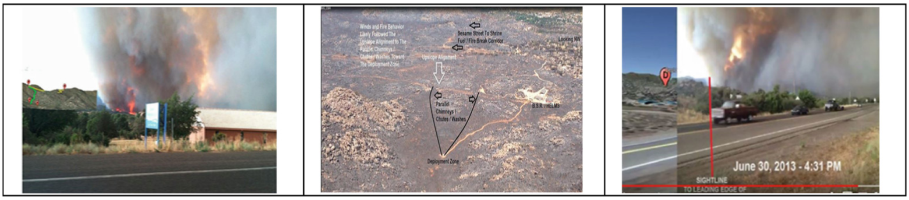

Fig. 1. Left (**1a**) photo - intense fire behavior 6/30/13 at 1629 h. from Assembly of God church along Hwy. 89 with Google Earth overlay - right icon is GMHS location, left icon is GMHS-descent point, lower icons are GMHS deployment/fatality site (DZ) and Helms (BSR) **Source:** Lauber, WTKTT, Google Earth. Middle (**1b**) photo - Enhanced Google Earth snippet image using Paint, aligned northwest, Sesame - Shrine Corridor leading to parallel twin chutes funneling upslope to GMHS DZ. **Source:** Google Earth, Collura. Right photo (**1c**) intense fire behavior 6/30/13 at 1631 h. along Hwy. 89. "D" is GMHS DZ **Source:** ABC News, WTKTT

clear sign of the normalization of deviance, drifting into failure; a progressive series of elements in a long chain of bad decisions with good outcomes setting up their inevitable fatal entrapment outcome [1, 2, 4, 7–9]. These factors may have impeded their decision-making: (1) cultural influences of municipal fire departments with collateral wildland fire responsibilities to "save structures" at all costs and consider FF safety as a "last resort;" [9] (2) known, obvious unsafe GMHS leadership concerns; (3) weak Crew cohesion that relied on consensus-seeking ("absence of leadership"); and (4) failing to know the situation(s) were getting out-of-hand (snowball effect), thus losing the ability to detect they were cognitively overloaded and needed to change plans or disengage [10]. One even deemed it "*an accident, just one of those things that happen.*" [9].

1.2 Motivation

Human Factors expert, Dr. Ted Putnam, wrote: Generally, the goal of accident reports is to convey as much of the truth of an event that is discoverable. Sometimes investigators deliberately distort or do not report all the causal elements, leading firefighters to distrust these reports, which can hamper our efforts to stay safe [4, 11]. 'Wildland firefighting is a high-risk occupation, shown each year by deaths or injuries in the line of duty. Identifying causal human factors to mitigate them in the future is critical.' [6]. The authors allege the USDA has been exceptionally deceptive. Given all this, how are true, intended complete "lessons learned" possible? Veteran WF Bruce Hensler points out that it does no good to identify or share any "lessons learned" if the industry that needs to learn them refuses to do so [12]. Putnam believes [WFs] will continue to die as long as they fail to come to terms with certain realities by acknowledging … the ***recurring failure to learn from lessons***." (emphasis added) [11].

2 The Sesame Street and Shrine Fuel/Fire Break Corridor Area(s) Firing Operations

At least twenty (20) people, including veteran WFs and FFs and the two YH Fire hikers watched a video in July 2013 at the Yarnell, AZ Library of a Sesame Street and Shrine

Corridor firing operation; also viewed by one FF on YouTube before it was removed. The video abruptly vanished without a trace, like other YH Fire evidence. There were also burnt fusees (firing devices akin to large road flares) found on a 2014 site visit and a GMHS family member found "*accelerants*" with specialized dogs another time [4].

Former YFD Fire Chief Peter Andersen (RiP) validated: "we built an emergency escape route for Yarnell ***in case there was a burnout like this*** … in that area below The Shrine, west of The Shrine, they had dozers back there widening that so that it would create a fire break, …" [13] WFs and local FFs regarding it as so, acted accordingly.

3 Wildland Firefighting Rules - Human Factors, Human Errors, and Human Failures

All WFs are trained in specific rules, crucial to follow to ensure good direction, leadership, safety, and vigilance. The strict Standard Firefighting Orders, organized purposely and sequentially, are to be carried out sensibly on all wildfires [1–3]. The 18 Watch Out Situations, (i.e. guidelines), are faced on all fires, more to warn of impending dangers. The authors and experienced WFs contend that knowing and abiding by the wildland firefighting rules works. They urge sound leadership and safe decisions [6]. There are no documented wildfire fatalities when the Standard Firefighting Orders are followed and the cautionary 18 Watch Out Situations ("10 & 18") are mitigated [14]. Sadly, there is a crusade afoot by current and former WFs and Managers to discredit these based on the SAIT conclusion, i.e. *"they did everything right and still died."* [4].

The most critical of the established Wildland Fighting Rules are listed in the (NWCG) Incident Response Pocket Guide (IRPG) [1, 2, 15]. Again, if WFs follow the Standard Firefighting Orders and are alerted to the 18 Watch Out Situations, much of the risk of firefighting can be reduced saving tens of thousands of WF lives each fire season [1, 4]. It is well-known and accepted in the WF community that these tried and tested rules work when applied consistently and with sound, decisive judgement [1, 2, 4, 6, 9].

Inexplicably, the National Interagency Fire Center (NIFC) urged YH Fire investigators to ***withhold some findings from the public,*** and to ***avoid analyzing whether crews violated fundamental fire-line rules*** in the AZ Republic (NPR) [16]. Restating, there are high-level criticisms by some alleged WF "*leaders,*" by way of the Wildland Fire LLC (WFLLC), that the WF Rules "*cannot work … not going to keep us safe*" and we need to rely on "*luck decision conversations.*" [15]. The authors and most WFs agree on the validity of the WF Rules, disregarding "*luck decisions.*" Abiding by defensive WF Rules and human factors is missing in most fatal wildfire investigation reports [14].

When asked by ADOSH investigators, alleged GMHS "lookout" McDonough, just moments after admitting that it was 'policy' for the GMHS to always '*risk a lot to save a lot*' in Wildland Firefighting (i.e. Fight fire aggressively, having provided for safety first, the 10&18, LCES, etc.) - he said: *"It's – it's hillbilly. It's what it is. … It's old. It's, uh, no offense to whoever came up with that, um, I mean no disrespect to anybody, but, I mean, it is the way they fight wildland fires today … is, I mean … Oh it's … We're smart. We're a lot smarter."* [17]. So smart, that with this cavalier safety attitude, his entire Crew, except one, was killed! In his book defending his Brothers' actions, he confirms this, *never* citing safety rules. A third year GMHS had to be coached on this.

Consider now (below) several of the human factors inferred from the text above.

3.1 Willingness to Properly Refuse Risk and Turn Down Protocol

It is largely agreed that wildland firefighting is a quasi-military venture; one is to obey orders unless unsafe, illegal, unethical, or immoral [1, 2]. It is located in the IRPG (p. 19) [16]. Confidently, it is safe to say that *all* WFs and FFs (notably supervisors) will be placed in these situations during their careers. *Most importantly, in every instance, they mustsatisfy their supervisory duties to ensure their respective individual and shared safety and welfare - no matter what!* So then, *why* did the GMHS fail to heed this on June 30th?

3.2 Plan continuation Bias

A potent, unconscious cognitive penchant, impeded the GMHS' ability to know they needed to change their course of action. Avalanche fatality scholars note people generally have a strong bias for sticking with what they have now and let their minds default to what is given or what has already been decided. They rely on stay-the-course impulses all the time, often with deceptively satisfactory results [18].

According to a Wildland Fire Safety Training Refresher (WFSTAR) poster, it was '*52 min from the blowup to the burnover*,' [4, 19]; yet the GMHS failed to notice obvious cues during that time period - instead "*discussing our options*," indicating that conditions were exponentially shifting - virtually screaming to them to '*stay in the black.*'

3.3 Steady Drift Into Failure Via Bad Decisions With Prior Good Outcomes

Several instances of GMHS hazardous attitudes and actions support their drift into failure spanning from their first official Hot Shot status season in 2009 up until the YH Fire in 2013. These involved a repeated attitude of having to "*prove themselves*" or "*one-up*" other HS Crews on fires, conspicuously due to their Municipal FD status [9].

On the 2012 Holloway Fire in NV, their Crew Carriers were saved by an Oregon-based Contract Engine Crew in this VIMEO video. (http://vimeo.com/48411010) [9]. Based on acquired public records, this was the second of three times another Crew had to "*save*" their Crew carriers - on the Holloway, Sunflower, and YH Fires [9].

GMHS Brandon Bunch was sick and tired of the GMHS Supt. always acting like he had '*something to prove.*' "[H]e felt that under Marsh's command, the Hotshots were always having to prove themselves" (p. 54) [20]. Is it safe to infer that the GMHS *normalized* deviance again and again? Or more so with sneaky good outcomes? [1, 2, 4, 9].

3.4 Consequences of Inattention as Causal Factor

Credible research on '*inattentional blindness*' (IB) reveals that when someone is otherwise engaged, at times they fail to "see" obvious clear, fully visible, yet unexpected objects or events, IB also leads one to miss items that one *needed* to experience [2]. If an event meets their belief(s), they may be more likely to exhibit IB for a sudden, possible critical visual event [2]. *At least two of them had to take notice* [2]. This likely occurred as they discounted so many signs and - *minus a lookout or notifying Air Attack* - *hiked* *downhill into the friendly fire, raging uphill fire behavior from the likely Sesame Street - Shrine firing operation.* (Fig. 1) [21]. AFUE transcripts show Marsh ordered air support ahead of GMHS [4].

3.5 Tunnel Vision and Auditory Exclusion

According to John Hopkins Univ. researchers Yantis and others, "*When attention is deployed to one modality, it necessarily extracts a cost on another modality. The brain can't simultaneously give full attention to both.*" [21]. When the subjects directed their interest to visual tasks ("*tunneling in*"), the parts of the brain that record auditory stimuli registered decreased activity. And when they focused on listening to spoken messages, brain areas that respond to visual images showed less activity. Perceptual distortions can occur at any point (e.g., when the information is received, retained, or recalled). *The mind will see what it expects to see and miss or misinterpret other potentially significant details* [21].

In fact, this is an exceptionally well-known hazardous injury and fatality causal human factor requiring critical training for those in law enforcement and the military.

3.6 Groupthink

Groupthink is the mode of thinking that people engage in when they are deeply involved in a cohesive group, when the members, striving for unanimity override their motivation to realistically appraise alternative courses of action [22]. When a major proposition was the group's that displayed groupthink symptoms, this was more likely to produce poor decision outcomes, more likely to display symptoms of defective decision making, resulting in poor policy outcomes. Group decision-making and decision-making support for a commander is acceptable. Military units utilize group decision-making techniques to develop tactical plans and recommendations that assist the commander in making decisions during battle. When groups work well they are more superior to individual decision making abilities [22]. In mountaineering, a group's cohesion results from the shared pursuit of a shared goal rather than from strong social bonds between members [23]. Flawed decision making turned a hazardous summit attempt into a fatal one. Climbers fatally failed to adhere to the strict turn-around time. Favored directive leadership entails telling followers what needs to be done, and giving proper guidance along the way [23]. The authors and many WFs and FFs deem it was Groupthink that led these men to follow their leaders to their deaths.

3.7 Destructive Goal Pursuit

Ignoring potential hazards and thinking only of what you set out to achieve, sets one up for disaster. Why would a group still pursue a goal despite mounting evidence that it could not be attained? [24]. In part, because research indicates that the greater the insecurity a group feels of their chance of achieving the goal, the harder they'll try. With failure more likely, the more rooted they are [24].

Failure indicators then cause the group to put even more effort into achieving the goal. Why? It's engrained in us. The more difficult the obstacle, the greater the achievement. Goals once set, are very hard to abandon. It's difficult to let it go.

Goals also actually limit learning. Goals cause people to take risks they might not think to take otherwise. *A decisive point - wanting something badly enough can cause you to ignore your gut feelings. That's destructive goal pursuit.* Failure to develop individuals within an organization can be disastrous. Teach climbers, and thus WFs, to make sound decisions for themselves, rather than be overly reliant on their leaders.

3.8 Friendly Fire

In the military, a casualty circumstance applicable to persons killed or wounded in action mistakenly or accidentally by friendly forces. In wildland fire, there are a few familiar cases of errant firing operations to blame for WF deaths [21].

4 USDA USFS and OGC Employee "Direction" and "Guidance"

4.1 Obstructive Touhy Regulations and the Federal Housekeeping Statute

Between the "Touhy Regulations" [U.S. ex rel. Touhy v. Regan, 340 U.S. 462 (1951)] and the plenary Federal Housekeeping Statute, 5 U.S.C. § 301 [33], the USDA USFS has ensured that their BRHS and USFS AFUE employees *will not be interviewed* [4, 25].

This legal minefield ensures there will be *no* '*complete lessons learned*,' described by BRHS Frisby, regarding the relevant planned Staff Ride human factors, accuracy, and veracity, as addressed in the email excerpts below. Frisby and the BRHS hold a wealth of YH Fire and GMHS information from June 30, 2013. *What is the USFS afraid of?*

4.2 USDA USFS Blue Ridge Hot Shot (BRHS) Crew and YH Fire Staff Ride

Consider excerpts from an April 2016 email from BRHS Supt. Brian Frisby to USFS National Human Dimensions Specialist Joseph Harris regarding the YH Fire Staff Ride. BRHS Supt. Frisby noted: "**the [YH Fire Staff Ride] picture being painted is very different than what we remember**" and that "**there was so much that went on that day that [was] swept under the rug**" and "**the human factors that day were off the chart.**" (emphasis added) [4] Per Touhy warning, no BRHS was ever interviewed [25].

5 Conclusion and Recommendations

"*If, as teachers of history will tell us, failing to learn the lessons of the past dooms us to reliving those lessons, then we must either impress indelibly into the minds of firefighters the lessons of the South Canyon Fire or we will again experience its tragic outcome." (Gleason and Robinson, 1994)"* [27]*(emphasis added) Student of Fire* [28] *commenter Matt adds: "It is unforgivable that we allow sentiment and tradition [to] prevent us from learning anything from the human factors surrounding Yarnell because* *we continue to be blinkered and sentimental in our eagerness to 'not speak ill' of the dead. It is nothing short of astonishing that the official conclusion was that everybody involved in the Yarnell Hill Fire did everything right - despite the incineration of the 19 hotshots by flames so hellish that granite boulders fractured. Covering up facts because they make us uncomfortable dishonors the dead, and ensures the same mistakes will be made in the future."* [28] (emphasis added) NONE of these are "hindsight bias."

The authors made a good faith attempt to share new information regarding some of the human errors that occurred on the June 30, 2013, YH Fire with the GMHS. New evidence is revealed regularly. There are an untold number of WFs, FFs, citizens; and family, friends, and loved ones of these same individuals that hold a lot of valuable information about the historic wildland fire lie, cover-up, and whitewash in photos, videos, human factors, and lessons learned narratives that need to be brought forward and shared. These valuable facts and insights will add greatly to *true* "*lessons learned*" to reduce wildfire fatalities, replacing the "incomplete" lessons we were force-fed [8].

WFs and FFs still talk about the numerous wildland fire fatalities that *continue* to occur - from the very *same* causal factors. Staff Rides are certainly a valuable asset in the "lessons learned" toolbox to reduce them. This noteworthy, yet ignored, key sentence - entirely on point - deserves attention: "**A staff ride should avoid being a recital of a single investigation report. Such reports rarely address the human factors that affect individual decision-making. … providing participants with a variety of information sources is important** [26]. Recall that *all* wildland fire fatality investigations are based on predetermined conclusions and the Staff Rides are based on these cover-ups, lies, and whitewashes [4]. Nonetheless, the YH Fire *demands* many "information sources" so as to be even mildly factual linking the fully omitted human factors.

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Continuous Stress and Consequence on C4t, Complexity, Risk, and Necessity of Leadership Level 5

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Abstract. The stressful environment installed in the workplace within the industry or in areas where the population lives in cities, affects people in different ways. The vectors that promote this stressful environment can be physical, organizational, cognitive, social, and affective within a network of relationships that result in inclusion, or frustration, both movements of a dichotomous relationship between comfort and discomfort. The organizational-social and affective pressure for results within the expectation of a socio-affective bond with work will result in a greater or lesser cognitive load that affect psychological functions causing mind map instability. Some tests indicate the level of stability of these psychological functions inherent to the work environment and citizen. It is important to keep intact the perception of scenarios, level of attention, operations of memory, identification of patterns. This paper will treat a vacation family as a task and will present SARS Methodology and Tools.

Keywords: Stress · Human elements · Level 5 leader · SARS methodology

1 Introduction

The stressful environment installed in the work within the industry or in the areas where the population lives within cities affects people differently. The human and social typology, and cultural aspects, change this influence of the stress on the work. Specialized tools are used in dynamic simulation, surveys, and historical data statistics to understand about the bad actors in accidents. We know that the stress is a capillary phenomenon and then, difficult of control. The vectors that promote this stressful environment can be physical, organizational, cognitive, social, and affective within a network of reward and punish resulting, or inclusion, or frustration, both dichotomous movements between the comfort and discomfort.

2 Literature Review

This review aims to present concepts about effect of continuous stress on decision, and what the demands to Level 5 Leader are, that need to use C4t [1]. The failures or the

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deviances arising from human action [2] contribute to accidents in the industry. There are 2 types of human errors: unintentional ones, generally considered accidental, such as triggering the wrong button, forgetting to open a valve; and the unintentional, the actions committed or omitted without any prior thought. Intentional deviances are actions that are committed or are deliberately omitted because it is believed that the action performed are correct and will be more efficient than the prescribed actions [2]. The existence of an inverted U-shaped mathematical relationship between stress and human performance was confirmed by [3]. The performance reaches the maximum and, from stress above normal, the performance is reduced, according to the Yerkes-Dodson Act.

Physical vectors can be indicated as temperature, presence of chemical and biological contaminants in the atmosphere, both excessive rain, and heat. According to [4], stress is a state produced by changes in the environment, which is perceived as threatening, challenging or harmful to the dynamic balance of the person. The nature of stress is variable. An event or change that produces stress at once may not generate the same reaction at another. It is observed that a person can feel challenged and motivated to face threatening situations. It is necessary to adapt to the changes, so that the person regains balance and reaches the energy and capacity needed to meet the new demands. It consists in the process of dealing with stress, a compensatory process with psychological and physiological components. In the discussion of organizational vectors, it is understood as actions of the organization on the individual, the pressure for results or threats to undue behavior or communication. The question of being due depends on perception of the abnormality and tendencies that change over time.

A Level 5 Leader is important and certain responsibilities of communicating a failure, a deviance, a near miss, then attributing value to the initiatives that have arisen from the group of operators for the events contingency. This leadership has the fierce determination to achieve goals, along with its work team, in addition to the technical competence that leads the group to trust him. In the elaboration of a scenario close to reality, it is sought to understand the best practices in contingency actions, when different styles of leadership occupy the same function in an event, what is the best decision and attitude when mitigating the resulting damage in a plant of continuous process. The stressor vectors or agents must be controlled, therefore being considered a charge, and the C4t [1] must be preserved to be able to resist the stressor vectors. The type of task on the other hand can help or hinder, in case of technology or product change. The leader has a big role to play on this routine operation represented by a vacation trip indicated in Fig. 1. The cognitive and social vectors depend on the feeling of security incorporated in the work environment or in the citizen's environment. Thus, there is a dynamic negotiation between the intensity of the vector and the resulting stressful environment. Organizational-social and affective pressure the worker for results within the expectation of a social-affective-work link will result in a certain cognitive load that can affect psychological functions and destabilize mind map for decision.

3 A Story: Industry Task or Trip in Family?

A vacation trip of a family (Fig. 1) shows relations in cooperative way to achieve the goals of comfort, safety, low cost, and harmony. In a Chemical Industry, we have the same experiences, every day, every shift, every production campaign. We believe that we can project this trip to have a good journey where each one of this family or of this work group have some of these behavior characteristics in a good level. In average, we consider a worker group, safe, alert, and resilient if they can work together with the same objectives based on Behavior Human Elements, Managerial and Technological.

Project for a Trip. First, as we presented in brief, we need to understand and avoid that the stressors agents or vectors or environments be present and affect the quality of work. We need to project this trip reducing the level of stress. In the case of family trip, each component assumes some roles. The understanding about the task is the second more important thing to be known, in the intention of a successful journey. Then, task planning including risk assessment and reliability calculation are important to measure the results of task and correct the performance shaping factors involved in this trip. We are following indicators to keep the journey in correct speed, way and comfortable for everyone in the car. Some parameters are calculated: time, quality, safety events, quality of communication, cooperation, and commitment, finally, level of stress, complexity, and necessities for training. The father is the driver that must be a leader in the routine and in emergency during the trip vacation. But, in some cases, the leader can be another unit from the family, the wife, for example. In actual times, where we live a low tolerance in social relations and new social conflicts, we need a leader to work in process safety, independent of the age and what part of family is. This leader must have competence, experience, active hearing, fierce determination, empath, admits own errors, simplicity, capacity to reproduce idea in write and voice in a form that people understand [5, 14]. The other important component of family in the trip is the wife that represent the competence necessary to finish the journey. When we understand about the concepts, the causal relations, and when do not believe only in the obvious events, then we have conditions to assume risks in the itinerary.

Ok, let us talk about the children, the girl understands what everyone thinks, try to follow the development of the team, understand that the family is a unit, as the shift group is a unit, and create an affective link between each other with rituals, common stories, and rites. The girl is the spirit of the group representing the cooperation in hard times that people are more and more depressive. The boy is spontaneous, like to talk with everyone, he is a smiling boy, loves to talk with different people from different culture. The boy has a good perception about reality and communicate in verbal and write form with common words, correct reports, and do not hidden notifications. The boy represents the communication that is fundamental part in a Just Culture. The dog is part of family, it is committed and loyal to leader and help and protect people.

Trip Story. The human factors (HF) are operational routine aspects in the social, organizational, managerial, human, technological classes, that can induce human errors and future deviances, failures, accidents, or disaster. After discussed this subject in form of HF network and respective Human Elements [16]. We are representing the human factors by points 1 to 6 (pt1–pt6) with respective events in the road map.

(POINT1) Although initially, the trip project was perfect to the family, the times changed, and the project do not attend the new requisites from the environment and culture. Something unknown happened and caused big vector of stress, and they, the family, do not know how to treat this hazard, a new virus in the region of trip with new behaviors from a population that do not believe in the future. **(POINT2)** The wife (competence) and the husband (leader), after knowing the news during the trip, did a new risk assessment and decided to change the direction of the trip, turning left, do not following to the north, in case of industry, maybe changing the production campaign. **(POINT3)** At this time, the stressors vectors increased potentially (cognitive and physical) affecting the trip and, the daughter (cooperation) talked with the son (communication) that suggested to the group a stop in the way. They need to rest from the stressed trip in a little and safe hotel. For 3 days they stayed on a beautiful place, far from the hazard direction. **(POINT4)** They changed the direction and new frontiers of different languages appeared, the mountain became more difficult to achieve the target, they needed new targets after a group discussion to avoid a new great risk, a storming. The family needed and installed a new navigation tool, more complex. The wife spent one day to understand how to operate this new device. **(POINT5)** Everyone was tired and needed to stop in a place near a region of forest. The commitment of the dog helps the family to find a safe motel to rest during the storming. The dog has an excellent sense of direction and believe that the new targets are possible to be achieved. **(POINT6)** A Teamwork try to achieve the target to control routine and avoid emergency. The case of this vacation trip can be used as a guide to prepare competences to human reliability.

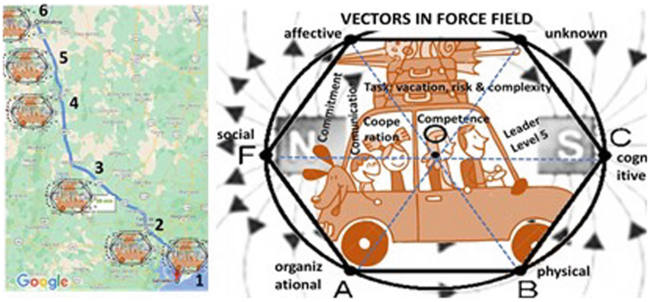

Fig. 1. Trip in family and behavior under stress influence.

4 SARS Methodology

The researchers of the group GRODIN developed this methodology with real cases, in a partial form, testing in practice, we named as SARS. We applied each activity in different cases of Oil and Gas, Chemical, and Metallurgical Industry. In Fig. 2 we present SARS Tool [6], an important step to achieve Just Culture in the risky facilities. The methodology has PDCA features, and after diagnoses and intervention we have critical analyses and rebeginning with new observation and data collection.

1. **Identify Operational Context:** Routine-Emergency operation mode. Initially we organize the strategy in this case of Technology and Organization. A data collection

requires strategies to understand the problem and targets. The classification of human errors, bad habits and wrong decisions allow some tests in routine, principally review of explicit routines, correction of explicit behaviors resultant of bad habits. In this way we can construct the preliminary scenario, we say initial impact. In family case, we say that the common risks are understandable before the trip, then they know the barriers.

2. **Task Assessment:** Indicators, Barriers, Failures, Review & Control. The initial diagnoses are based on task assessment after deviances occurred and a failure happen. In our experience, the stability of social-technical barriers in threatening environment is not safe. Then some critical tasks need monitoring and changes in case of new hazards or new failures in barriers. In case of family trip, we have the appearance of new unknown hazard, an epidemy. The Discourse of operator, Abnormal Events Map, Human and Technology typologies, mathematical and statistical tools indicate probable root causes modes based on Operational Culture. When we find the causes, we can install safeguards to avoid recurrence of failures.
   The interventions will be applied to avoid impact consequences in the production system. The classical correction activity is reviewing the procedure and training the team, but it is efficient only for simple cognitive gaps in routine. Sometimes we need behavior correction or recover of beliefs on the company and leaders, then we need educational programs, with change of informal rules, rites, managerial profile. The treatment for bad habits originated by archetypes against safety is based on education, new rituals, and justice sense established in the organizational practices. Other interventions involve new tools of communication and reproject of interfaces.
3. **Culture Assessment, Preliminary Step, and Final Step.** When we investigate the type of human error, the informal rules in the operational routine, the failure mode of the critical task, the beliefs, and rituals active in the group. When investigating the organizational procedures for communication, leadership, and cooperation, we can discuss expected behaviors of the team and indicators for the safety culture. During the time we follow the indicators and test new procedures, rituals, and organizational practices to adjust aspects of the culture. Maybe we need to change the indicators too.
4. **Behavior Investigation and Social-Human Failures.** The observation of routine and characterization of human errors allow to elaborate a measurement plan to C4t aspects about behavior. In case of family trip, the personage's behavior is followed to establish a plan to keep the best targets during journey. The C4t characterization, measurement, and control try to create a safe environment with calibrated attention to be resilient if events became failures that became accident.
5. **Human Factors and (6) Human Elements Identification.** From now until the journey end, final of shift for example, we must construct a human factor network represented by a sequence of events and safeguards (human elements) to keep the task in control. We need to monitor the quality of leadership, the metrics of behavior and culture to adjust the interventions or behavior safeguards.

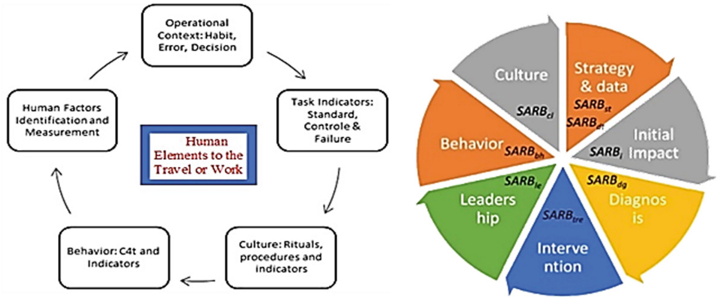

Fig. 2. SARS method & PDCA

5 Application: Oil and Gas, Chemical and Metallurgical Facility

Industry Operational Context of Oil and Gas Plant. Inflammable gas, problems of quality (water) and logistic (availability of raw material) incur operational problems during the routine. The plant interface project suggested controls that do not operate well and cause maintenance problems becoming difficulty to achieve a good performance. **Task Indicators.** In case of oil refinery [15], we know that little accidents are caused by a complex relation between contracted enterprise in logistic area and the owner of principal business. The human element, complexity (HE1), is calculated by level of attention, memory, process control and others. In this way, the case of forklift accident in refinery, yields a complexity 79 between 3 to 1000. This parameter will be used to calculate the social technical reliability. The other indicator is about the risk considered and discussed in GCPS [7, 8] published tools about Preliminary Risk, Stress, and Social HAZOP, all including human and social factors at Chemical and Oil industry (HE2). Other indicators of human reliability integrated to equipment, process and operation reliability was published in [9] in case of propene transportation achieving the value of 86%. In case of Oil & Gas Plant, with high cognitive pressure for results we collected information about the shift participants and how many components work in double time and how many warnings of failure we have in a shift. In this case, the stress environment caused by double work cause noises in communication or in cognition causing deviances and possibility of failure, we say double work is derivative indicator of stress level (HE3). The SARS Tool implementation needs the classification of human errors, bad habits and wrong decisions in derivative way. In Gas facility investigation we created a form to classify human error based on project, environment, task, cognition, and behavior, we found 52 derived human errors.

Culture. The Stressor Vectors cited in family trip influence the Magnetism conflict in dominance culture phenomena. These vectors affect HE3, stress level, and HE4, Leadership level. We discussed a lot the effect of this cultural conflict causing social failure in the fertilizer public company [10]. We discussed too about the influence of archetypes and construction of failure in task performing using executive function model in cases of chemical industry [11, 12]. **C4t Tool – Behavior at Work.** We understand that is possible to manage subjective aspects of worker behavior treating the human elements in C4t step, part of SARS Tool [6]. Some indicators were tested in Oil & Gas and Petrochemical Industry. We understand that emotional state is based on cultural aspects, cognitive quality, and possibility of psychosomatic diseases, giving in Gas Industry a final value of 7 from 10 and standard 8. In case of commitment we consider worker information as time at company, if married and how many children, and other personal information. We tested giving as result 3 groups were 30% in high commitment level (HE5). The level of cooperation is based on aggregation (AG) and disaggregation (DAG) parallel movements, in the Oil and Gas indicating, AG = 6.8 from standard 8, DAG = 5 from standard mean of 5.4 (HE6). The competence analyzes is based on the human errors during long period of shift, 2–6 months, and task results. In this period, we can elaborate the cognitive and behavior gaps and create an exam that will be applied in operational group and indicate the training and behavior necessities to avoid the accidents (HE7). Finally, Ávila and Drigo [13] elaborated Organizational Communication Model to measure the quality (omissions and commissions) of ascendent, horizontal and descendent communication (HE8).

6 Process Safety Leader 5, A History in Stressful Workstation

The level 5 leader (L5L) of an isocyanate chemical plant is referred to in this paper as Teacher J or TJ. The term teacher has a great meaning, while this leader refers to the partner as "teacher", the L5L adopts the student posture, which must observe, listen before speaking or acting. While the classical leader makes his own value extreme and pressures his partner-listener to a minimal role, that of student. Now, the L5L communications flow without the power relationship, events of underreporting diminish. Thus, the urgency of certain activities or actions becomes apparent. The fierce determination is another important feature of TJ, the time passes and the hazard energy that can be released in this isocyanate plant, has a speed where certain actions require this assertive decision. On the other hand, the classical leader who allows the information to circulate makes decision-making possible without knowing exactly what is happening in the plant. TJ has learned from plants with Japanese technology that agendas should be followed in a disciplined manner, where sampling, transfer, loading, startups, and plant shutdowns require differentiated attention. Part of this activity with team redundancy, and another part being performed by only one operator. By understanding the operation of the plant, it is easier to define the interventions. Operation only occurs if pre-set patterns are followed to the letter.

In the case of the classical leader, where the absence of root cause study, acceptance of flexibility in operator behavior and differentiated treatments, make decisions too much in punishment or even too much in non-discipline. Following the procedure is the pattern of this leader, but not realizing the scenario and checking the differences for the best decisions. At the time of the awards there is no concern of L5L in being prominent. He often, on the contrary, admits certain faults as his to enable the flow of information from the shop floor and does not care about the ceremonies of social gain. On the contrary, the classical leader is always the person closest to the truth and makes a point of receiving "almost all the laurels" of the goal achieved.

Informal relationships are part of the L5L strategies while formal ones, which are accepted by the top level of the organization, become the concern of the classic leader who turns his team into a tool to achieve the ends. The L5L is concerned with field skills and the passage of knowledge from the more experienced to the younger or even the skills of diffused attention to focused and focused to diffuse. The classic only respects the organizational chart and often does not preserve the ability.

TJ, when discussing with the staff that some procedures are incorrect, shows that at each moment, depending on the operator and the criticality of the activity, an adjustment is necessary in the language and at the level of detail. At times, the engineer of the staff exaggerates writing a common activity in detail leading to disbelief by the group of operators. Finally, there is a personal characteristic present in the L5L, besides the simplicity, there is a great value assigned to the family.

7 Conclusion

In a very clever way, the article presents a parallel between the daily hypotheses that are lived under the effects of stress in a continuous way, both in family matters and in the professional environment. A simple vacation trip where the main objective is the search for rest and family life can become an unpleasant situation and to be forgotten, as well as in the work environment where the common goals are the search for quality work, controlled risk and cost within budget can be transforming into heavy and high-risk tasks. The SARS tool can be easily applied in these situations experienced under continuous stress and can generate a continuous monitoring of the risk conditions of the activities due to the search for continuous improvement brought about by the PDCA effect of the tool. In addition, it makes clear that situations of high or continuous stress need to be led by people prepared for this, emphasizing that the classic leader contributes negatively to the process. Decision making conducted by a L5L is always the best evaluated and accepted by the team even in high stress situations.

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Professional Deformations of Bailiffs with Different Professional Efficiency

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Abstract. The study purpose is to identify and describe the professional deformations types of bailiffs with different professional efficiency. Research methods are questionnaires and multivariate statistical analysis methods. The study used the author's questionnaire for assessing the professional deformation types and work performance subjective assessment by law enforcement officers. The study involved 277 federal bailiffs service employees of the Arkhangelsk region. The bailiffs are characterized by a high level of such professional deformations as overcontrol, conservatism and authoritarianism. By means of a two-stage cluster analysis, all employees are divided into three groups according to the professional performance level (low, medium and high) according to their subjective assessment. Bailiffs with a low professional performance level are distinguished by a higher professional aggression, behavioral transfer, conservatism and learned helplessness level. Authority, overcontrol, and anxiety do not have statistically significant differences in groups, which may be due to their positive impact on employee performance.

Keywords: Bailiff · Professional deformation · Work performance

1 Introduction

The federal bailiffs service (bailiffs) refers to the authorities, which provide for the passage of only the federal civil service. In this case, the bailiffs perform actions inherent in law enforcement officers. The most accurate, from the V.N. Oparin's point of view, is the following definition: law enforcement agencies include special organizations that protect the rights and freedoms of a person and a citizen, as well as the state itself, which are formed for the implementation of specific goals, namely, the protection of a citizen from criminal encroachments, the protection of law and order and public safety [1].

According to the Regulations on the Federal Bailiff Service in the Russian Federation, bailiffs conduct inquiries in a number of criminal cases categories, look for debtors, ensure order in the courts [2].

This fact explains the special requirements for candidates for service. The bailiff-executor professional activity main characteristics include: high responsibility and stress resistance level, high working capacity, communicability, poise, the ability to

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quickly adapt, high noise immunity, attentiveness, switchability, observation, developed emotionally - will sphere [3].

Psychological support measures aimed at professional deformations early diagnosis and prevention in service teams are great importance in maintaining the law enforcement specialist's health and performance.

Professional personality deformation is an objective phenomenon, the negative effects of which can be eliminated only through other, non-professional factors (socialization, education, etc.). This is the process and result of the person's subjective qualities influence, formed in accordance with the certain professional work specifics, on the personal properties of the worker's integral individuality [4].

The professional deformations development negatively affects not only the workers' personality themselves, but also their activities performance in general. Therefore, in E.F. Zeer's this phenomenon definition as a criterion for the professional deformation severity, included a negative impact assessment on the professional performance. In our study, we will take this factor into account [5].

In our previous studies, a classification and diagnostic tool for assessing seven police officer's professional deformation types was developed [6]. Due to the similarity of the police and bailiffs' activities nature in terms of ensuring the citizens safety, ensuring buildings and premises protection, bringing persons, the authority to draw up protocols on administrative offenses [7], we consider it possible to adapt and apply it to assess the bailiff's professional deformation severity.

A scientific studies number have shown not only the negative professional deformations impact, but also the positive [8]. The criterion for these differences can be the professional performance characteristics, since it reflects the employee's performance degree and quality, as well as their interaction peculiarities with management, within the team, with citizens, as well as "a price of activities" - changes that arise in a human status as a result of its implementation.

In this regard, the relationship study between the professional performance and professional deformations types will allow to determine the positive or negative influence vector in the employee's personality on the professional duties' efficiency.

The study aim is to identify and describe the bailiff's professional deformation types features with different professional performance.

Research hypotheses are: 1) the professional personal deformation classification, developed for police officers, can be adapted for bailiffs due to the similarity of their official activities' characteristics. 2) the relationship between the professional deformation types and professional performance makes it possible to determine the positive or negative effect of their severity on the bailiff's performance.

Research stages:

1. To determine the bailiff's professional personal deformation types severity.
2. To classify bailiffs into groups depending on their subjective assessment of the professional performance.
3. Conduct a comparative analysis of the professional personal deformation severity among bailiffs with different professional performance self-assessments.

2 Study Design

The study involved 277 federal bailiff service employees of the Arkhangelsk region. Of these, 58 are men and 75 are women between the ages of 24 and 59 (average age: 39.5 ± 8.18 years); average length of service is 10.15 ± 5.95 (maximum service length is 26 years). According to the division, all the subjects were divided into structural divisions as follows: 8.3% employees holding a managerial position (department head, deputy department head); 46.9% - bailiffs-executors; 23.3% - bailiffs to ensure the established procedure for the court's activities; 18.8% - other positions employees.

In this study, we rely on the previously developed law enforcement officers' professional deformations classification and a subjective assessment of professional performance (Ya.A. Korneeva, O.E. Kuznetsova, A.Yu. Barmina, M.A. Tunkina).

The questionnaire includes three sections:

1. general information about the subjects (age, sex, marital status, education level, position, rank, work experience);
2. aimed at identifying the professional deformations severity (Fig. 1). The section includes 30 questions, the answer to each of which can be: constantly; often; sometimes; not. Each deformation type severity is in the range from 25% to 100%.

Deformation type	Deformation description	Examples of questionnaire questions	Number of questions in the questionnaire
Authoritarianism	Inflated self-esteem of their professional abilities, imperiousness, aggressiveness. Psychological defense - rationalization.	Do you also give instructions in cases when it is not within your authority?	6
Professional aggression	Strengthening stereotypes of thinking, reducing self-criticism and the ability to constructively resolve conflict. Psychological protection - projection.	Do you use ironic statements and ridicule in business and interpersonal communication?	6
Super control	Excessive containment of feelings, suppression of spontaneity, orientation to instructions, suspicious discretion.	Do you always strictly adhere to the instructions in the work?	4
Behavioral transfer	It is manifested in their behavior, emotional reactions, speech, intonations, the psychological characteristics of offenders are clearly manifested. Decreased speech culture. Psychological defense - projection.	Do you use profanity at work and outside of work?	3
Conservatism	Stereotyped ways of performing an activity. Social barriers. Psychological defense – rationalization.	When solving professional problems, do you use the same solution method?	4
Irresponsibility or learned helplessness	Avoiding responsibility, non-initiative fulfillment of professional duties, formal attitude to responsibilities, increased delegation.	Are you a proactive employee?	3
Anxiety	Constant anxiety, difficulty and sometimes inability to concentrate on something, muscle tension (for example, in the face, neck), irritability, sleep disturbance, scrupulous control of activity.	Do you find it difficult to concentrate on something while working?	4

Fig. 1. The bailiff's professional deformation types description and examples of questionnaire questions to assess their severity

3. aimed at the professional performance self-assessment (on a seven-point scale). The criteria assessed by employees are shown in Fig. 2.

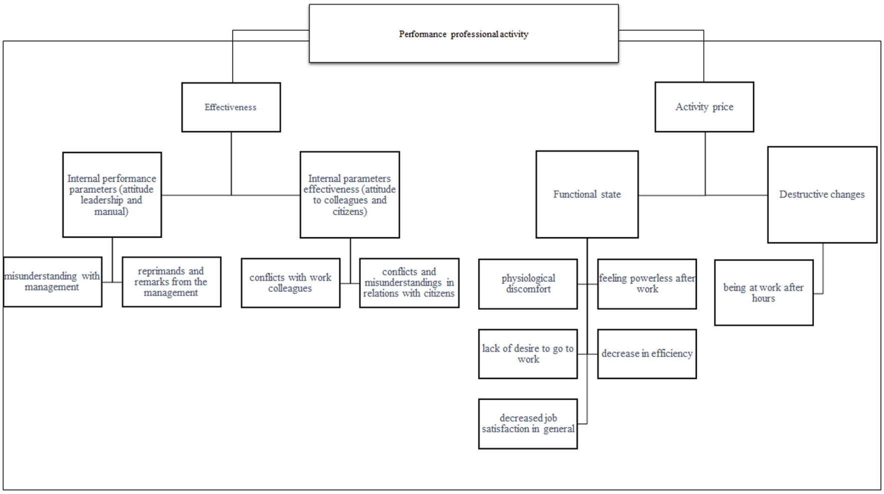

Fig. 2. The professional performance criteria, assessed by questionnaires means

3 The Bailiffs' Professional Deformations with Different Professional Performance

3.1 The Bailiffs' Professional Deformations Types Severity

Table 1 shows each professional personal deformation type severity (assessment is presented as a percentage from the maximum possible score for the deformation type in each of the surveyed).

Table 1. The bailiffs' professional deformations types severity (% from maximum score on the scale, n = 277).

Deformation description	First quartile	Median	Third quartile
Authoritarianism	45,8	54,2	58,3
Professional aggression	33,3	37,5	45,8
Super control	68,8	75,0	81,3
Behavioral transfer	25,0	33,3	33,3
Conservatism	37,5	56,3	62,5
Irresponsibility or learned helplessness	33,3	41,7	41,7
Anxiety	25,0	37,5	43,8

As can be seen from the data in Table 1, bailiffs are characterized by a high overcontrol level, which is expressed in excessive discretion, scrupulous control of their professional activities, and orientation to the approved instructions. The bailiff's activities include ensuring the safety of the participants in the trial in the courts, and, if necessary, arresting them with their subsequent transfer to the police, etc. The average authoritarianism level may be associated with the fact that this activity presupposes power of authority (using physical force possibility, special means and firearms, and the implementation of citizens personal searches, etc.).

The average conservatism level is associated with strict activities regulation, but employees also need flexibility to respond quickly.

Despite the fact that the bailiff's activities are diverse, related to the citizens detention, the court hearings protection, and sometimes the special equipment use, most of the time employees regulate issues with debtors. This activity, like most trials, takes place in normal conditions and does not imply extremeness. In this regard, the propensity to anxious manifestations in bailiffs is reduced.

Behavioral transfer is the least pronounced among the bailiff's deformations, since there is no intensive communication with offenders compared with the punishment service and the police, where frequent and long-term contacts are made with them.

Learned helplessness also has a low level, which may be related to the employee feedback presence on performance results. This is ensured by the establishment of planned targets for the number of completed enforcement proceedings for structural divisions and for each bailiff separately. Thus, they can assess the effectiveness and quality of their activities.

3.2 Analysis of the Bailiff's Professional Performance Subjective Assessment

To study the professional deformation relationship with the professional performance subjective assessment parameters using a two-stage cluster analysis, all the surveyed were divided into three clusters, statistically different in the activity performance self-assessment characteristics: the first cluster - 27.2%, the second - 46.2%, the third - 9.7% of surveyed employees. A qualitative clusters description the is presented in Table 2.

The first cluster employees are characterized, first of all, by job satisfaction in general and the desire presence to go to work (these indicators have the lowest value in the sample). They are characterized by low physiological discomfort, minimal conflicts with colleagues and management, as well as with citizens. Thus, this cluster employee's performance assessment will be considered high.

The third cluster parameters assessments differ significantly from those considered above. High indicators for such features as powerlessness, lack of satisfaction, disagreements with the management, feel a decrease in efficiency. All this allows us to assert that the third cluster employees have low self-esteem of their performance.

The first and third clusters have maximally polar characteristics values, and therefore, the second cluster will be considered a group with an average performance assessment.

3.3 The Bailiffs' Professional Deformity Types Feature with Low, Medium and High Professional Performance

In order to identify differences in the professional deformation types severity among bailiffs with different professional performance, a multivariate analysis of variance

Table 2. Average values of the professional performance parameters self-assessment by 1, 2 and 3 clusters representatives

Parameter	1 cluster	2 cluster	3 cluster
	M ± SD	M ± SD	M ± SD
Physiological discomfort	1,7 ± 0,54	2,2 ± 0,64	2,8 ± 0,94
Conflict with colleagues	1,6 ± 0,45	1,9 ± 0,51	2,7 ± 0,75
Misunderstanding with management	1,5 ± 0,56	2,3 ± 0,86	3,3 ± 1,15
Reprimands and remarks from the management	1,5 ± 0,59	1,9 ± 0,70	3,3 ± 0,81
Conflicts with citizens	1,8 ± 0,83	2,3 ± 0,84	3,1 ± 1,14
Decreased performance	1,5 ± 0,58	2,5 ± 0,73	3.11 ± 0,85
Feeling powerless after work	1,5 ± 0,63	2,3 ± 1,00	3,8 ± 1,30
Lack of desire to go to work	1,2 ± 0,43	2,0 ± 0,65	3,3 ± 1,25
Working overtime	3,9 ± 1,48	4,5 ± 1,49	6,3 ± 0,94
Decreased job satisfaction in general	1,3 ± 0,46	2,4 ± 0,80	3,9 ± 1,41

was applied, where the professional personality deformation types were the dependent variables, and the fixed factors were attribution to one of three clusters in terms of performance parameters (Table 3).

Table 3. Comparative analysis of employee's various professional personality deformations types severity (% from the maximum possible score) belonging to different clusters according to the professional performance assessment based on the MANOVA results (n = 277)

Professional deformations types	1 cluster with high performance	2 cluster with medium performance	3 cluster c with low performance	p- significance level
	M ± SD	M ± SD	M ± SD	
Authoritarianism	54,5 ± 9,28	56,0 ± 9,28	54,5 ± 8,71	0,409
Professional aggression	39,4 ± 7,78	45,2 ± 8,27	49,3 ± 11,47	<0,001
Over control	69,3 ± 11,40	68,4 ± 12,88	66,9 ± 14,62	0,595
Behavioral transfer	33,2 ± 7,46	38,4 ± 10,22	44,5 ± 10,54	<0,001
Conservatism	51,6 ± 12,11	57,5 ± 11,14	62,0 ± 10,17	<0,001
Irresponsibility or learned helplessness	37,3 ± 10,15	39,0 ± 10,35	41,7 ± 10,73	<0,001
Anxiety	54,5 ± 9,28	56,0 ± 9,28	54,5 ± 8,71	0,409

First of all, we need to analyze the statistical significance of variables. So, important for consideration features of the professional performance subjective assessment are professional aggression, behavioral transfer, conservatism, and learned helplessness (at $p < 0.001$).

Employees with low professional performance have relatively higher scores on statistically significant scales. The bailiffs with high performance are significantly lower. However, the absolute parameters values in the group with reduced performance do not exceed 70% of the maximum possible, that is, they are expressed moderately.

Thus, the typical behavior for bailiffs with reduced professional performance may be the physical force use without the appropriate ground's presence, unpredictable evaluative reactions; jargons use, tendency to disruption, formal attitude to activity, initiative lack, poor flexibility, desire to simplify tasks, restlessness and physiological discomfort.

Earlier we noted that professional deformation can have both negative and positive impact on the employee and his activities. It is worth paying attention to the following deformations: authoritarianism, anxiety, and overcontrol. Despite the fact that they are not statistically significant for us, we consider it necessary to consider their manifestations in the selected groups of effectiveness.

Overcontrol differs significantly from other deformation types. It is most pronounced in the group with high performance. It can be assumed that this indicates a positive effect on the employee's performance, since the manifestations of overcontrol (namely, inhibition of feelings, orientation to instructions, discretion) are necessary conditions for the successful completion of tasks.

It should be noted that authoritarianism is approximately equally expressed in employees with high and low performance. With an increased authoritarianism manifestation, it can have a negative impact, that is, excess of power functions, criticism intolerance. In a situation with an average most deformations severity, authoritarianism will not have such a negative effect. Rather, this species will be displayed in a high assessment of its capabilities, the desire for recommendations and orientation of colleagues or citizens in any situations.

4 Results Discussion

The results obtained can confirm the fact that with an increase in the certain professional personal deformation types severity, the employee's performance decreases. For bailiffs, these are professional aggression, behavioral transfer, conservatism and forced helplessness.

At the same time, authoritarianism, anxiety and overcontrol do not have such links, but on the contrary, contribute to the professional duty's performance. To establish the revealed phenomenon causes, it is necessary to analyze the relationship between the severity of these deformation types and personality traits from among the employees' professionally important qualities. Which will be this research continuation. We assume that compensatory qualities and properties will be revealed in the professional suitability structure. For their development, it is necessary to develop and implement training programs for personnel.

Thus, the results obtained allow us to draw a conclusion about the similar professional deformation types severity of bailiffs and police departments, as well as the possibility of using the developed author's questionnaire to assess their severity in bailiffs.

5 Conclusion

According to the study results, in most employees the various professional personal deformation types severity is moderate and is in the range from 25% to 75% from the maximum possible when measured. Over-control, authoritarianism and conservatism were shown relatively higher than others, lower values were obtained for the parameters of behavioral transfer, anxiety and helplessness. The bailiffs are characterized by a high professional deformations level such as overcontrol, conservatism and authoritarianism.

By two-stage cluster analysis means, all employees are divided into three groups according to the professional performance level (low, medium and high) according to their subjective assessment.

Bailiffs with a low professional performance level are distinguished by higher professional aggression, behavioral transfer, conservatism and learned helplessness levels.

Authority, overcontrol, and anxiety do not have statistically significant differences in groups, which may be due to their positive impact on employees' performance. Their moderate severity in the presence of harmonizing features can contribute to the successful implementation of the professional activities of bailiffs.

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Digital Safety

Short Circuiting the Controller – Missteps in Maintenance and Inspection of Process and Wiring in STS-93

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Abstract. During the launch of the Chandra X-Ray Observatory in 1999, an in-flight anomaly occurred a few seconds after liftoff. A power fluctuation caused two Main Engine controllers to drop offline. Fortunately, due to redundancy, the Space Shuttle Columbia was able to successfully reach orbit and avoid an abort. After the successful deployment of Chandra and the safe return of the crew, investigation revealed that the controller failure was due to a wire short in the payload bay. It was suspected that the Kapton insulation on the wire rubbed off against a burred screw head, the result of overtightening of the screw during a maintenance event 4 to 5 years prior to the STS-93 mission. Vibrations led the abraded wire to short during flight. The Space Shuttle Program was grounded for 4 months while a program-wide inspection and wire chafing mitigation effort of all orbiter wiring ensued.

Keywords: Human factors · Human-systems integration · Systems engineering · Human factors engineering · Wiring · Safety · Maintenance · Training · Arcing · Maintainability and supportability

1 Introduction

1.1 Mission Objectives

The primary objective of the Space Transportation System mission 93 (STS-93) was to deploy the 50,000-lbs., $1.5 billion Chandra X-Ray Observatory. Chandra, the world's most powerful X-Ray telescope, would allow scientists from around the world to study some of the most distant and dynamic objects in the universe. Stripped of nearly 7,000 pounds of its own gear to make room for the payload, the orbiter assigned to this mission was Space Shuttle Columbia (OV102). Prior to STS-93, Columbia had 25 flights and was NASA's oldest orbiter.

On March 15, 1998, Eileen M. Collins, a Colonel in the U.S. Air Force (USAF), was selected to command this mission, making her the first woman ever to command a Space Shuttle mission. She led a crew of four astronauts: Jeffrey Ashby, a Captain in the U.S. Navy and pilot of the Shuttle, and mission specialists Catherine G. Coleman,

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USAF Lieutenant Colonel, Steven A. Hawley, Ph.D., and Michel Tognini, French Air Force Colonel.

Columbia was scheduled to launch on Tuesday, July 20, 1999, at 12:36 a.m. EDT from the Kennedy Space Center (KSC) in Cape Canaveral, FL.

1.2 July 20, 1999: Ready, Set… Cutoff?

At 12:36 a.m., Eileen and her crew sat aboard Shuttle Columbia on Launch Pad 39-B at KSC, ready for launch. Ralph Roe, the Shuttle Launch Director, had just given Eileen and her crew the go for launch and wished them good luck. Just shy of T-minus 45 s on the countdown, everything was looking good for launch. For the next half minute, the countdown continued smoothly. At T-minus 10 s, the Ground Launch Sequencer (GLS), the program that inputs commands to perform the final critical tasks to put the vehicle in launch configuration (monitoring as many as 1,000 different measurements), gave Columbia's computers the go to start the engines. the final countdown began – "T-minus 10… 9… 8… 7… CUTOFF!… We have uh… hydrogen in the aft".

Between the 10-s and 7-s mark, the hydrogen burn-off igniters started. The orbiter's hazardous gas detection system indicated a 640 PPM concentration of hydrogen in Columbia's aft engine compartment, which was more than double the allowable amount. Leaking anything is never good news but starting the engines with leaking hydrogen can be catastrophic.

Without a second to lose, Ozzie Fish, the primary hazardous gas system engineer, called out for an immediate stop. Barbara Kennedy, the primary GLS engineer, initiated a manual cutoff of the GLS less than a half-second before the Shuttle's three main engines would have started at the T-minus 6 s mark.

Eileen and her crew exited the shuttle and at 1:30 a.m., the engineers convened to study the problem. Following the preliminary system and data evaluation, the launch team determined the indication of the hydrogen leak to be a false positive. From this, there was good news and bad news. The bad news was this false alarm led to a 48-h launch scrub turnaround. The good news was, (besides the obvious being that the crew and vehicle were safe) due to the quick reaction of Ozzie and Barbara, the launch sequence was stopped in the nick of time, saving the team from a week-long turnaround.

Take-two of the STS-93 launch was rescheduled to be in two days.

1.3 July 22, 1999: Don't Rain on My Parade

The external hydrogen burn-off ignitors at Launch Pad 39-B were replaced after the first launch scrub, and the countdown clock began again. Forty-eight hours following the prior launch attempt, weather officers identified a storm cell in the area that produced lightning strikes within 8.5 miles of the launch pad. According to the shuttle launch criteria, lightning-producing storms cannot be closer than 20 nautical miles from the launch site. At the T-minus 5-min mark, the countdown clock was held, pending weather clearance. Roe even added 10 min to the launch window, but it seemed like the storm was there to stay.

After much-anticipated waiting, at 1:20 a.m., the launch was officially scrubbed, and attempt three was re-rescheduled in less than 24 h.

1.4 July 23, 1999: Third Time's the Charm

"Eileen, the weather is cooperating tonight, and the launch is ready to go", Roe stated for the second time in three days, giving Eileen and her crew the go for launch. At around a quarter past midnight, the countdown clock began. At T-minus 9 min, the GLS auto sequence was initiated.

A smooth six minutes went by, and at around T-minus 3 min, the pressurization of liquid oxygen and liquid hydrogen tanks began. A couple minutes before launch, the Launch Control Center sent a final message to the crew of Columbia: "A few days delayed, but the same enthusiastic launch team wishing Columbia's crew success on your mission". Eileen responded, "Thanks for all the great work, and we'll see you in five days".

At T-minus 31 s, the GLS issued a go to Columbia's onboard computers to start their automatic sequence. At T-minus 10 s, the spark igniters near the main engine nozzles burned off residual gaseous hydrogen, and the final command from the ground computers was given to start the engine.

At T-minus 6.6 s, the three engines started and came to a full thrust: "5… 4… 3… We have a go for engine start… 0… We have booster ignition and liftoff of Columbia reaching new heights for women and x-ray astronomy!".

After the fairly uneventful countdown, Columbia was still not in the clear. Everyone remained on the edge of their seats as Columbia blasted off. For any launch to be successful, there are a list of things that need to go right, but for a failure, only one thing needs go wrong. All within the first few minutes of flight, problems arose that could have resulted in either a Return to Launch Site (RTLS) Abort or Loss of Vehicle and Crew (LOVC).

Problems During Ascent. About five seconds after launch, Mission Control at Johnson Space Center announced, "AC bus sensors off. We're evaluating the fuel cell". They detected a voltage drop on one of Columbia's electrical buses. As a result of this power fluctuation, a primary and back-up Main Engine controller, DCU-A (digital computer unit) on the center engine and DCU-B on the right engine (highlighted in red in Fig. 1), dropped offline. Thankfully, that still left at least one working controller, AC-2 and AC-3 highlighted in yellow and blue, respectively, for all three engines.

If there had been any other AC bus issues, it would have caused one entire engine to shut down. Ultimately, the redundant set of DCUs in each engine controller saved Columbia and her crew from a very risky contingency abort.

As the ascent continued, the engines cut off 0.15 s too early due to low liquid oxygen level, which caused an orbiter underspeed of 16 ft/s. The low-level liquid oxygen cutoff should not have happened since an adequate reserve is always loaded. However, this early cutoff did not necessitate an abort to orbit (ATO), but the attained orbit was seven miles short of that originally projected.

For the remainder of the ascension, the center and right main engines functioned smoothly and the orbiter underspeed was still within the acceptable margin allowing Columbia to successfully climb to orbit. Although a few miles short of the initially

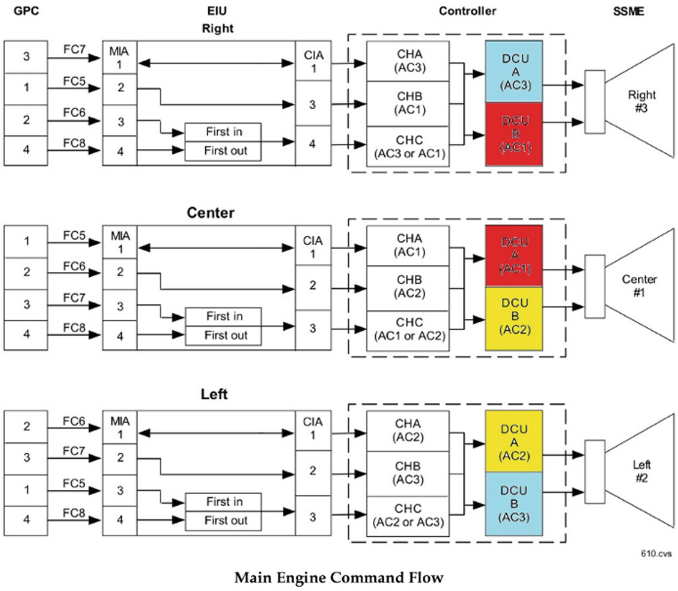

Fig. 1. A diagram from the shuttle crew operations manual showing how the main engines were wired for redundancy. NASA image

projected orbit, the orbiter eventually attained the proper altitude. After successful confirmation of the engine shutdown and orbital insertion, Flight Director, John Shannon commented, “Yikes. We don’t need another one of those”.

Mission success - Chandra was deployed!

2 Underlying Issues

2.1 Wiring

What caused the voltage drop that resulted in the loss of the electrical buses? The post-flight inspection revealed soot on a screwhead and a hole in a stretch of 22-gauge Kapton insulated wiring (Fig. 2). The single strand of AC current carrying 14-gauge polyimide wire was located nearly half-way down the payload bay. The Shuttle Independent Assessment Team (SIAT), formed in September 1999 to do an assessment of the Shuttle Program after this mission, reported that the wire had rubbed and chaffed against a burred screwhead. This burr was later determined to be the result of over tightening by a technician during a maintenance refurbishment. Then, during another ground processing event possibly years after, somebody inadvertently stepped on the wiring harness causing some of the Kapton insulation to rub off against the burred screwhead. SIAT suspected the wire damage was pre-existing and was caused 4 or 5 years prior to the flight.

Fast-forward to the launch – the power was turned on with the vehicle sitting on the launchpad, so systems confirmed there was electrical flow through those wires. What

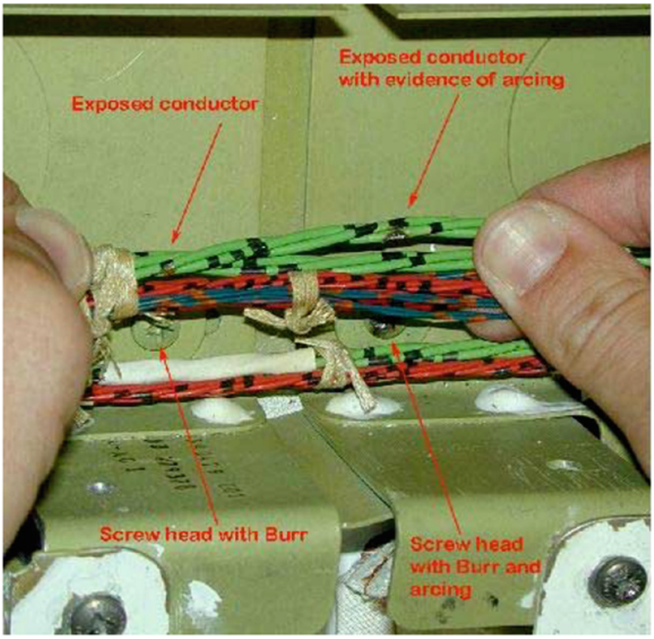

Fig. 2. Carbonized insulation due to arc damage. NASA image

really set off the arcing of the wire was the vibrations of the vehicle during launch. A common saying amongst NASA engineers is "Test like you fly, fly like you test". Unfortunately, in this situation, there was no way to test by recreating the vibration by a launch. See Table 1 for summary of events leading to the loss of AC buses.

Table 1. Series of events leading to the wire short during STS-93.

When?	Maintenance event A	Maintenance event B	Launch day – vibrations	Launch day – wire short	Launch day – voltage drop
What happened?	Overtightening of screwhead by a tech resulting in a burr	Technician stepped on the wire harness causing the wire to chafe against burred screwhead	Vibrations during the launch sequence was enough to allow contact between the exposed conductor and exposed metal area on burred screwhead	Wire arced to the burred screwhead and shorted	Voltage drop caused the failure of the AC 1 inn 2 of the 3 Space Shuttle Main Engines

2.2 LOX Post Pin

In the Space Shuttle Main Engines (SSME), hot hydrogen gas is mixed with cold liquid oxygen (LOX) in just the right way to protect the engine through the start transient, main stage, and the shutdown transient. The way this is done is the LOX is first introduced through stainless steel tubes called LOX posts (Fig. 3). The robustness of the tubes is generated from the cooling by the LOX inside and the heating by the hot hydrogen outside.

Huge forces work on the LOX posts, especially during start up when the vibration forces are high. If one were to break off there could be possible LOVC. Therefore, to eliminate the potential of a LOX post failure, inspections of posts are performed using ultrasound. It was common practice to deactivate a post if it showed signs of wear or fatigue. To deactivate a post, a gold pin was hammered into the LOX post supply orifice (Fig. 4) and a vacuum leak check was performed. The tapered gold LOX pin, measuring about $1''$ long and 0.1 in. in diameter, was responsible for shutting off the LOX flow through the post, reducing high-cycle fatigue loading. In the history of the program, 212 LOX posts were pinned in this way including STS-93. There had been 19 prior instances of pin loss during ground testing with no impact damage.

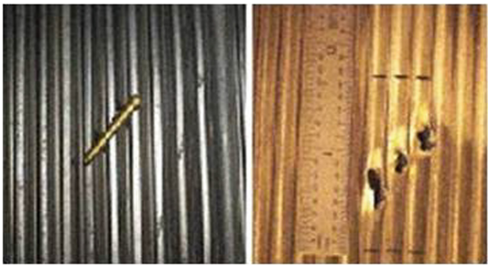

Fig. 3. Ejected LOX pin and 3 ruptured tubes. NASA image

After Columbia landed, post-flight inspection of the affected right engine indicated that LOX post 32 in row 13 had shot out and ruptured the narrow part of the converging nozzle and into the nozzle extension. Three nozzle coolant tubes out of five were breached (Fig. 3), causing a hydrogen leak into the hot steam of gas coming out of the engine. Consequently, triggering the premature engine shut-off. The LOX pin shot past the three tubes and also dinged the Main Combustion Chamber but there was no penetration of the coolant channels there.

To all observers – human and digital – it appeared that the right amount of hydrogen was going into the engine because the leak was downstream of the hydrogen flow meter. Analysis showed that if the shuttle had lost five or 6 tubes, there would be a localized hot spot on the nozzle that could potentially burn through and end in a loss of the whole engine.

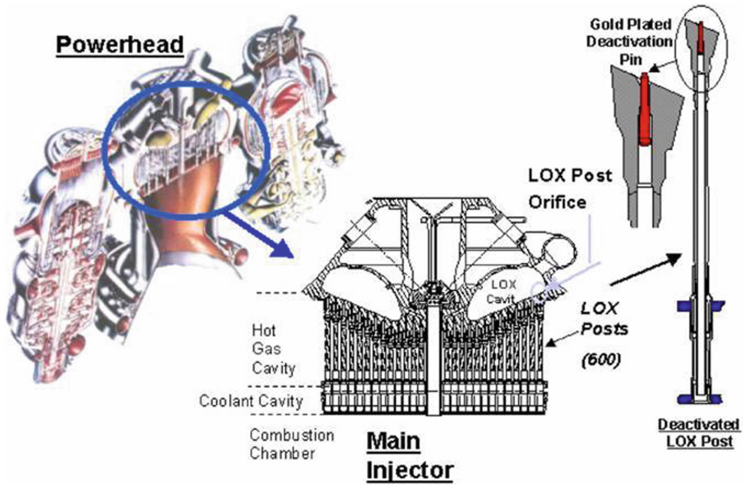

Fig. 4. Powerhead, main injector and liquid oxygen post details. NASA image

3 Conclusion

Due to the in-flight wiring anomaly, the shuttle program was grounded for 4 months and led to a program-wide inspection of the wiring of all orbiters including Columbia. The NASA Space Shuttle program (SSP) determined that the root cause of this anomaly was workmanship. Corrective actions taken by the program included detailed inspection of all mid-body wiring and selected inspection of additional wiring, repair of wiring damage, redefining and standardization of wire inspection criteria to allow for less damage, and additional protection was added to selected critical wiring. The return of the Shuttle to flight status was based on repair of wire damage, wiring failure mitigation by overall Orbiter design, and maximum feasible separation of redundant systems. Other recommendations included quantifying and evaluating the current wire visual inspection processes, certifying technician/inspector by specially trained instructors, and minimizing the long-term use of polyimide wiring.

The ejection of the LOX post pin incident brought on a maintenance practice change that required damaged oxidizer posts to be removed and replaced as opposed to being intentionally plugged. During the engine block changes, Main Injector manufacturing processes were improved to preclude liquid oxygen post damage. There are no pinned posts in the fleet anymore. All STS flights starting with STS-103 used either Block II or Block II-A Space Shuttle Main Engines. None of these engines had deactivation pins in any of the liquid oxygen injector posts and it was not planned to fly any more pinned posts since 1999.

Appendix: SIAT Assessment

The SIAT was chartered by NASA to provide an independent review of the Space Shuttle sub-systems and maintenance practices. During the period from October through

December 1999, the team led by Dr. Henry McDonald and comprised of NASA, contractor, and DOD experts reviewed NASA practices, Space Shuttle anomalies, as well as civilian and military aerospace experience.

Wiring In-Flight Anomaly
Corrective Actions:

Maintenance Requirements. Each Shuttle vehicle contains over 200 miles of wiring throughout the vehicle. As with modern aircraft, Shuttle wiring is a critical system since multiple failures can lead to loss of a vehicle. The primary wiring used in the Shuttle is a nickel-plated copper conductor with 6 mil thick polyimide/FEP insulation (similar to MIL-W-81381, trade name "Kapton", a wire construction extensively used in aviation from the early 1970's to mid-1990's). While this insulation has performed well in many applications, there are known issues related to arc track propagation (carbonization of polyimide and rapid collateral damage to adjacent wiring), mechanical degradation when exposed to certain environments (ultra-violet radiation, high pH materials (>10), sustained long term exposure at elevated temperatures to moisture while under mechanical stress), and insulation cracking when the insulation is nicked and placed under tensile stresses. Polyimide wire insulation performs best in straight runs with minimal bending and flexing. Examination of the Shuttle mid-body would seem to be the ideal application for this type of wiring. The extensive wiring damage found on each vehicle appears to be related to the high and continuous exposure to personnel performing maintenance procedures on various Shuttle systems.

Inspectors have been encouraged not to conduct intrusive inspections to minimize induced wire damage. The most intense inspection has been conducted in the mid-body bays. An examination of the Problem Resolution and Corrective Action system data prior to recent inspections shows the mid-body area to be the fourth highest area with wire damage. The data as of November 18, 1999 shows that since the recent inspections in late August 1999, there have been 485 problem reports written related to wiring in the mid-body area.

Design Issues. According to an early 1990's NASA study, the redundancy in 318 criticality-1 (CRIT 1), which is a single failure that could result in loss of life or vehicle, circuits were compromised by placing the redundant circuits in the same wire bundle or clamp. There were 129 CRIT 1/1 areas identified that violate system separation requirements. NASA Standard 8080 requires that critical circuits be physically separated. As an example, six separate areas exist that, if compromised electrically, would result in the loss of all main engine controllers. A review of the data indicates only violations that could be eliminated required a waiver. At the time of this report, a review of criticality-2 (CRIT 2), which is a failure that could result in loss of mission, systems with respect to comprising redundancy was pending.

It is apparent the current wire tray design contributed to STS-93 wiring failures. The use of a wire tray allows wiring to touch metal surfaces, which has resulted in the wiring contacting screw heads and other sharp surfaces. A past and possibility current maintenance practice has changed tray design assumptions. The reuse of tray screws and an occurrence of burred screw heads have created an unexpected chaffing source.

There was also considerable configuration variability between vehicles. In some cases, additional chafe protection was added, or screw heads were covered with a protective coating. The wire bundles were permitted to move in clamps and the trays. Typically, critical circuits must be kept physically separated from all surfaces and other wiring.

Arc Tracking. Damage to wiring or insulation and aging of insulation are a concern to the Shuttle fleet. Several incidents have been recorded over the life of the program.

As the Shuttle fleet continues to age, additional problems are to be expected. Given the life expectancy of the Orbiters, it is essential to plan for maintenance related to aging, not solely for upgrades. As early as 1991, NASA documents reported that arc-tracking was a significant risk on the Shuttle, as identified in the following statement from the 1st. NASA Workshop on Wiring for Space Applications, held at Lewis [Glenn] Research Center in July 1991: "Arc propagation poses a significant and credible threat to mission safety and success in aerospace vehicles [Shuttle]. This workshop was attended by members of the Space Shuttle community including Johnson Space Center and was co-sponsored by NASA Headquarters, Code Q.

Arc tracking susceptibility has not been eliminated, as this is an inherent property of polyimide insulation. Laboratory tests have shown that current circuit breaker technology does not sense arc track events. Intermittent arcing is seen as a varying load by thermal circuit breakers and current spikes can exceed over 1000% of a circuit breaker's rating without tripping the device. Arc track events have occurred with one- and three-amp circuit breakers; many of the Orbiter circuits are protected by three-amp breakers. Circuit breakers can also fail and not trip during an electrical short.

Human Factors

Findings:

1. Communication difficulties exist between all parties particularly in accepting feedback from the workforce, Aerospace Safety Advisory Panel, and independent assessment groups. This factor erodes trust and loyalty within the workforce which are essential for safe work practices.
2. Failure to incorporate Human Factors as a critical part of the decision process has increased potential single point and multiple point failures.
3. Recent numerous changes and transitions adversely affect work practices, resulting in loss of technical and process-related corporate knowledge (see Issue 7).
4. Process improvements made during the transition period to Shuttle Flight Operations Contract have also brought workforce concerns.
5. Work stresses, including expanded work assignments and diminished team support, have reduced the capabilities of the downsized workforce. Innovative cross training approaches may be key to regaining competencies and taking advantage of the skill and experiences of an aging workforce.
6. The SIAT is concerned that in spite of the Aerospace Safety Advisory Panel recommendations and findings, supported by the SIAT, recurring human factors issues remain unresolved.

7. Employee surveys, although limited in current scope, show significant levels of Physical Strain (internalized chronic stress). Internalized chronic stress has been implicated in workers suffering from stress related disease (e.g., gastrointestinal, cardiac, migraines).

Recommendations:

1. Communications between the rank-and-file work force, supervisors, engineers and management should be improved.
2. Human error management and development of safety metrics, e.g., Kennedy Space Center Shuttle Processing Human Factors team, should be supported aggressively and implemented program wide.
3. Selected areas of staffing need to be increased (e.g., the Aerospace Safety Advisory Panel advised 15 critical functional areas are currently staffed one deep).
4. The SIAT recommends that the SSP implement the Aerospace Safety Advisory Panel recommendations. Particular attention should be paid to recurring items.
5. NASA should expand on the Human Factors research initially accomplished by the SIAT and the Air Force Safety Center. This work should be accomplished through a cooperative effort including both NASA and AFSC. The data should be controlled to protect the privacy of those taking the questionnaires and participating in interviews. Since major failures are infrequent occurrences, NASA needs to include escapes and diving catches (see Appendix 3 of the full report) in their human factors assessments.
6. Work teams should be supported through improved employee awareness of stresses and their effect on health and work. Workload and "overtime" pressures should be mitigated by more realistic planning and scheduling; a serious effort to preserve "quality of life" conditions should be made.
7. Teamwork and team support should be enhanced to mitigate some of the negative effects of downsizing and transition to Shuttle Flight Operations Contract. Most immediately needed is the provision of relief from deficits in core competencies, with appropriate attention to the need for experience along with skill certification. Further development of the use of cross-training and other innovative approaches to providing on-the-job training in a timely way should be investigated.

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Machine Learning for Occupational Slip-Trip-Fall Incidents Classification Within Commercial Grain Elevators

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Abstract. The grain handling industry plays a significant role in U.S. agriculture by storing, distributing, and processing a variety of agricultural commodities. Commercial grain elevators are hazardous agro-manufacturing work environments where workers are prone to severe injuries, due to the nature of the activities and workplace. One of the leading causes of occupational incidents in all industries, including grain elevators, is slip, trip, and fall (STF). Therefore, prediction of STF incidents prior to occurrence is significant in occupational safety analysis. Despite high frequency of STF incidents at work, exploring their dominant factors via machine learning algorithms in agro-manufacturing environments is relatively new or unaddressed. Safety professionals may utilize the prediction and analysis of determinant factors of occupational incidents for actionable prevention and safety mitigation planning and practices. The objective of this research is to describe the slip-trip-fall (STF) injuries and trends in a population of agribusiness operations workers within commercial grain elevators in the Midwest of the United States, identify risk factors for STF injuries, and develop prevention strategies for STF hazards.

Keywords: Occupational safety · Occupational incident analysis · Machine learning · Decision trees · Bootstrap forest · Safety management

1 Introduction

Commercial grain elevators are significant in the agricultural sector in the United States due to their role in sorting, distributing and processing a wide range of agricultural commodities [1]. Compared to various sectors in agricultural-related industries, the cost and frequency of occupational incidents are higher in grain elevators [2–4]. This increase in recent years among agro-manufacturing operations within commercial grain elevators is due to the expansion in the grain storage capacity [2].

Among various causes of occupational incidents, slip-trip-fall (STF) incidents are a leading factor resulting in injury or fatality at workplace [5]. In the United States, STF

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is one of the most commonly reported external causes of occupational incidents [6] and the percentage of workers' compensation claims ranges from 7% to 44% across industry groups for falling on the same level [7]. The economic burden of injuries related to STF are significant [8]. STF occupational incidents account for 95 million lost workdays annually in the United States, and cost employers an average of $20,000 on workers' compensation expenses per incident [9]. Another study estimated the direct annual costs of STF-related occupational incidents as $6 billion [10].

In an analysis of nonfatal occupational incidents in Korea between 2001 and 2010, Rhee et al. [11] showed that slip and fall incidents showed a higher annual rate compared to fall from height incidents, specifically in construction, agriculture, and service sectors. The rate of occupational incidents in agricultural-related industries was greater than other sectors [12]. According to Aguila Martinez-Casariego et al. [13], workers in agriculture-related sectors were involved in a variety of operations, and therefore, were exposed to all types of physical, chemical, psychological, and ergonomic occupational hazards, with STF incidents as one of the most common ones. Agribusiness industries consist of all the operations and organizations involved in the production, sales, and distributions of crop and livestock commodities [14], and include agricultural suppliers, producers, commodity merchandisers, as well as food processors and retailers for human and animals [15].

The purpose of this study is to analyze the agro-manufacturing occupational STF incidents within commercial grain elevators in the Midwest of the United States, using Bootstrap Forest (BF) machine learning algorithm. The results will provide insight on the factors that influence differentiation in the cause of occupational incidents. In addition, the approach and results will contribute to the development of safety measure with focus on eliminating the hazard sources for the occurrence of STF incidents.

2 Materials and Methods

2.1 Data

The data for this study are the records of workers' compensation claims from 2008 to 2016 in the agro-manufacturing operations within commercial grain elevators. According to this dataset, out of 6328 recorded claims, 31% were caused by STF and 69% are non-STF. The data show a total loss of $85 million U.S. dollars from all incidents. Forty million and $45 million U.S. dollars were paid on STF and Non-STF incidents, respectively. This amount covered the medical and rehabilitation costs, costs of indemnity and days-away-from work, and other expenses as compensation for the injured workers.

2.2 Modeling Variables

The independent factors in the modeling are the characteristics of the occupational incidents that include *age*, *occupation* and *experience* of the workers, as well as the *type of injury* (medical or disability), the *injured body part groups*, and the *nature of injury*. The dependent variable in the study is the main cause of the incidents. According to the data, the STF incidents are 31% of the total cause groups. The other 69% classified as

Non-STF include other causes such as strain or injury by, struck or injured by, and heat or cold exposure. By relabeling those other than STF incident cause, we created a new binary variable for the main cause of the incidents as STF and Non-STF.

2.3 Bootstrap Forest Machine Learning Classifier

Decision trees are powerful machine learning algorithms for predicting and classifying various categories of interest in injury and incident analysis [16–18]. The bootstrap forest (BF) is an ensemble decision tree predictive modeling algorithm for classification and regression tasks. This method is specifically useful for modeling high-dimensional data and addresses the problem of overfitting by reducing the variance without bias increase during the process of training the model [19]. For each bootstrap sample of the training data, a tree is built using a random subset of the independent variables in the dataset, and the final mode is an ensemble model created by averaging all those decision trees [20]. Furthermore, the BF model can be used for sensitivity analysis of predictors' contribution to the classification performance by calculating the specific contribution of each independent variable as a predictor of the output class. This contributes in selecting the strong predictors of the output class.

2.4 Model Development and Performance Assessment

In model preparation stage of this study, the whole data are partitioned into training and testing sets with 70–30 ratio. Therefore, the data in training and test set includes 4746 and 1582 instances of occupational incidents, respectively. Considering the assessment of the model, we use accuracy rate, sensitivity, specificity, and F-score. These values can be calculated from the confusion matrix that shows the number of correctly versus incorrectly classified instances.

Based on the classification results in a confusion matrix, the measures of merit for the performance of the machine learning is calculated. The model accuracy *(TN + TP/Total)* shows how often the classifier is correct in labeling an output class. Recall *(TP/FN + TP)* show the effectiveness of the model in identifying positive labels. Precision *(TP/TP + FP)* show the class agreement of the data labels with the positive labels defined by the classifier model. F-score is the balance between recall and precision *((2(precision * recall)/(precision + recall))*. In this study, confusion matrix is built for STF and Non-STF as N, and P classes, respectively (Table 1).

Table 1. Confusion matrix for binary classification (in this study)

Actual class	Predicted class	
	STF (Negative)	Non-STF (Positive)
STF (Negative)	True Negative (TN)	False Positive (FP)
Non-STF (Positive)	False Negative (FN)	True Positive (TP)

3 Results

The BF model is first trained on 70% of the data. In the second step, the new data in the test set are fed into the already trained model to assess the predictivity and performance of the BF algorithm in classifying main cause of occupational incidents in this study.

3.1 BF Classifier Performance

After training the BF algorithm on 70% of the data, the model was applied on the test dataset, which includes 30% of the workers' compensation claims in this study. The confusion matrix for the classification of STF versus Non-STF incidents are built as shown in Table 2. The confusion matrix is then used to calculate the model performance evaluation values: overall accuracy, overall error, recall, precision, and F-score.

The overall accuracy for this classifier is 0.72 and the error rate is 0.28. Therefore, the BF classifier is able to differentiate between the STF and Non-STF incident causes in 72% of the instances correctly. The values for recall, precision, and F-sore are 0.98, 0.72, and 0.83 respectively. The recall value of 0.98 shows the model's performance in classifying Non-STF cases is significantly high. This is due to the high frequency of Non-STF (69% of total data) in records of occupational incidents. For STF prediction, the precision value of 0.72 is still high and shows that this model can predict correctly in 72% of the cases, the main cause of occupational incident as STF. This is significant considering the low frequency of STF incident causes in the data.

Table 2. Confusion matrix for test data.

Actual class	Predicted class	
	STF	Non-STF
STF	56	420
Non-STF	20	1086

3.2 Sensitivity Analysis

Sensitivity analysis is the method of estimating the variability contribution from the input variables in predicting an output [21, 22]. In order to identify the most significant contributors to the prediction of STF and Non-STF incidents, the variable importance plot is constructed for all the independent variables used in the study. Figure 1 shows the specific contribution of each predictor in classifying the main cause of an occupational incident as either due to STF or Non-STF.

Based on the sensitivity analysis, the strongest predictors of the main cause of incidents in this study are the nature of the injury, followed by the injured body parts as well as the workers' occupation and age. The type of injury and the experience years have a much less effect in predicting the STF versus Non-STF incidents. This agrees with previous literature that emphasized the role of occupation in incident cause predictive modeling due to the significance of work tasks and activities in determining the probability of safety risks among workforce in agribusiness-related industries [1, 23, 24].

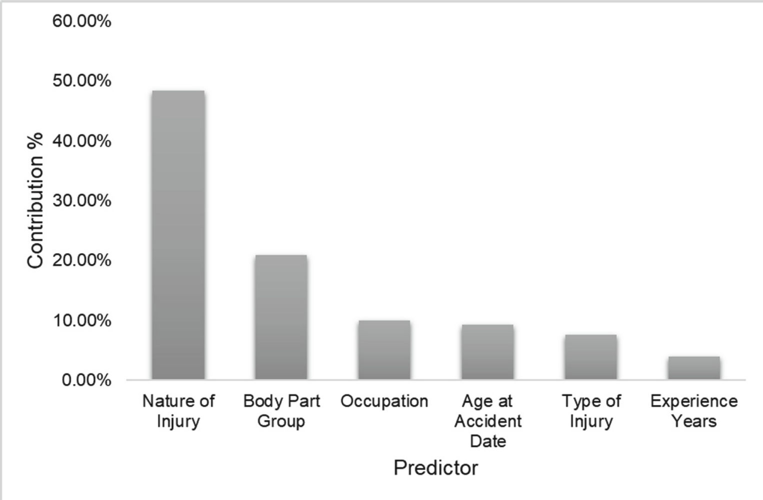

Fig. 1. Variable importance plot for sensitivity analysis.

4 Conclusion

We analyzed the occupational incidents within commercial grain elevators in the Midwest region of the United States and focused on slip-fall-trip incident causes as the source of safety risks. This study used over 6000 occupational incidents cases to investigate the influential predictors of occupational incidents cause in agro-manufacturing operations related to sorting, distributing, and processing of agricultural commodities within the bulk storage facilities. The modeling approach and the results of this study can be used together with safety practitioner expertise to improve informed decision-making processes in target work environments. Ultimately, this may reduce or possibly eliminate the causes of incidents, and consequently, improve the safety of the workers.

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Risk Exposure and Assessment

Risk Assessment Knowledge Relating to Occupational Health and Safety Risks: A Case Study of Five Finnish Companies

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Abstract. Conducting risk assessment in workplaces has proved to be demanding, even though it is essential in occupational health and safety promotion and accident prevention. To identify knowledge gaps regarding risk assessment in workplaces and related development needs in Finland, five medium- and large-sized Finnish companies were studied using semi-structured safety expert interviews. The interviewees (n = 10) highlighted the need to develop the assessment of the magnitude of the risk, the utilization of the risk assessment and residual risk, and the use of occupational health and safety systems. Further studies are needed to determine how to support risk assessment skills and evaluate the success of risk assessment in workplaces.

Keywords: Hazard identification · Occupational safety and health · Risk assessment · Risk evaluation · Workplace safety

1 Introduction

Risk assessment is an important factor in occupational health and safety (OHS) promotion and accident prevention. Nonetheless, in practice, it can be difficult to carry out a risk assessment, as identifying hazards and analyzing and evaluating risks in the workplace is challenging. Certain hazards are identified and not as well-managed as others [1]. Poor risk assessment and failure to identify hazards has been attributed to various factors, including subjectivity and skill gaps [2–4]. However, studies have shown that risk assessment skills can be developed, for example, through training and internships [5–7].

Teaching methods and commitment have emerged in the literature as important factors for the development of risk assessment skills. According to Albert and Hallowel [8], not all traditional pedagogical teaching methods are suitable for adults because they have different needs and expectations relating to teaching and learning compared to children. Hence, a learner-centric andragogical method has been developed for them [8]. In their study, Zuluaga et al. [9] found association between high-engaging training

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methods and higher hazard recognition level. The methods differ, for example, in terms of the need for knowledge, self-study, study experience, readiness to learn, and motivation. In addition to the training method, training transfer factors such as upper management commitment, supervisor support, safety culture, and different feedback have a major impact on better hazard recognition [10]. According to Namian et al. [10], the use of more engaging and more expensive training methods may not provide a better level of hazard recognition compared with traditional low-engaging methods if the level of training transfer is low. Hashem et al. [11] also found that methods of delivering safety training (such as text, lecture, and video) do not affect knowledge retention.

In Finland, according to the Occupational Safety and Health Act, employers have an obligation to take care of the health and safety of their employees [12]. Identifying hazards and potentially harmful effects is part of an employer's duty of care. The Finnish Ministry of Social Affairs and Health (MSAH) published *The Risk Assessment in Workplaces Workbook* [13], which is widely used. The MSAH Workbook offers a framework and guidelines for identifying hazards in OHS risk assessment. Checklists for various hazards (such as physical factors, ergonomics, chemical factors, psychosocial factors, and the risk of injuries) are included in the MSAH Workbook. Generally, companies have updated their checklists to suit their operations. The aim of this study was to identify knowledge gaps relating to risk assessment and related development needs in Finnish workplaces.

2 Methods and Materials

To facilitate a more in-depth understanding of the risk assessment knowledge gaps in five Finnish companies, a qualitative interview study was conducted. A semi-structured interview was used to collect the data, using a form with preprepared topics as a guide. The preprepared topics focused on the use of the MSAH workbook, the method used for risk assessment, employees' risk assessment skills, and how to develop risk assessment skills. The topics included questions such as the following: Who conducts the risk assessments? Which methods are used in risk assessments? What kind of risk assessment skills does the personnel have? How are the risk assessment skills evaluated? How is the success of the risk assessment evaluated? The semi-structured interview form was based on a previous study [1] and current research questions. The interviews were recorded and analyzed by categorizing the themes that emerged.

The companies represent the following industries: 1) manufacturing; 2) transportation and storage; 3) electrical power generation, transmission, and distribution; and 4) other technical testing and analysis field. Four of the companies are large, while one is medium-sized, employing about 200 people. In addition, the companies employ subcontractors. The companies were chosen based on their needs and interests to develop their risk assessment processes.

A total of five interviews were conducted. The job titles of the interviewees (n = 10) in the companies varied from safety engineer to health, safety, environment, and quality managers. Hereinafter, they will be referred to as safety experts. All the interviews were held in autumn 2020. Table 1 summarizes the distribution of the companies, the interviewees, and the interviews.

Table 1. Background information about the interviews (n = 5) and interviewees (n = 10).

Companies industry	Manufacturing (companies A and D); transportation and storage (company C); electrical power generation, transmission and distribution (company B); and other technical testing and analysis field (company E)
Interviewees per company	Company A (n = 2), company B (n = 1), company C (n = 3), company D (n = 3), and company E (n = 1)
Interview medium	Teams interviews (n = 5)
Interview type	Individual interviews (40%), group interviews (60%)
Duration of the interviews	Average: 73 min, range: 63–84 min
Experience in occupational safety	Average: 7 years, range: 2–15 years

3 Results

The participated companies mainly used electronic checklists customized for their use. Almost all of them used a matrix to determine the magnitude of risk. The checklists and risk matrices were mainly based on the MSAH workbook. The risk assessments involved the supervisor and the employee(s), the OHS officer and in some cases the safety/quality manager, and an expert. The companies did not evaluate the risk assessment skills of those who were performing the risk assessment or the success of the risk assessment.

In the interviews, four categories emerged as the main areas for development. The categories were related to difficulties in estimating the magnitude of the risk, the utilization of the risk assessment and residual risk assessment, and the OHS systems used. There also arose a question of how the results of the risk assessment should be discussed with the employees. Table 2 presents the four categories and explanations.

According to the interview results, assessing the magnitude of risk is difficult. The interviewees mentioned, for example, the varying views of experts, supervisors, and employees on the consequence and probability of the risks. The training provided by the companies to support risk assessment varied widely. Orientation for new employees includes information on safe work methods. Certain jobs require special qualifications, and in that context, OHS is also discussed. In addition, there were various in-house training videos, guides, and thematic training. As an example of management's commitment to safety, one company sent a group of safety experts to introduce a new OHS system to supervisors at their work sites. Moreover, it was found that although staff is trained, their ability to carry out risk assessments is not assessed or tested.

Even though the interviewees stated that discussing residual risks with employees can improve risk awareness, not all companies carried out a residual risk assessment. Some of the companies evaluated residual risk before corrective actions are completed, while some evaluated it after corrective measures. One issue relating to the utilization of residual risk assessment was measuring how often work needs to be rethought because the original plan would cause an occupational safety risk. In addition, it was argued that an audit-type residual risk assessment after corrective measures would also act as a quality assessment. Several interviewees shared the view that the results of both the risk assessment and the residual risk should be used more in orientations and training.

Using OHS systems requires instructions that are simple enough. Based on the interviews, there were differences in defining the consequences of hazards. Not all the systems provided sufficient guidance on hazard characterization. Because of that and not being aware of the principles of risk assessment, the employees were not able to determine what the possible consequences would be if the hazard is realized. As a result, the corrective action did not necessarily respond to the hazard originally identified. All the companies had an electronic risk assessment system configured for their use. In principle, the systems had similar functions. In this study, the systems themselves were not further examined. However, in general, some systems were perceived as complex. It was hoped that the system would guide the user through the risk assessment and would be easy to use. It was noted that the employees did not always know how to write all the considered matters clearly enough.

Table 2. Identified knowledge gaps and development needs relating to risk assessment.

Category	Details
Assessing the magnitude of risks is challenging	Due to the subjective view, a matrix may not be the best solution for assessing the magnitude of risk
	Supervisors' view of risks may differ from employees' view
Utilization of risk assessment	Results of the risk assessment should be used more in training and orientation
	A tool for supervisors to develop operations
Utilization of residual risk	Quality assessment
	Discussion with employees
	In orientation materials
Using the OHS-systems (for example, SaaS, PaaS, or intranet)	Instructions need to be simple enough
	Identified hazard and predicted consequence do not always meet

4 Discussion

In this study, insight into knowledge gaps in risk assessment in Finnish workplaces was given. Four main needs were identified to develop the risk assessment concerning difficulties in assessing the magnitude of the risk, the utilization of risk assessment and residual risk, and difficulties when using the OHS system. Nenonen et al. [14], in previous research among Finnish companies, found that the companies' risk assessment process is mainly based on the MSAH workbook, which is usually applied strictly. Even though companies adapt the checklists and risk matrices to suit their use, their use was perceived as problematic due to a subjective perspective. Others felt that the numerical assessment facilitated the prioritization and proper implementation of corrective actions.

The results of this study are in agreement with previous studies that have evaluated risk assessment in other industries. For example, Wijeratne et al. [15] studied maintenance activities in three organizations, and their findings on the subjectivity of risk assessment supported the results of this study, as the lack of standards has been found to complicate an objective analysis of the severity and likelihood of hazards. Furthermore, the use of risk matrices in risk assessments has received criticism [16, 17]. Likewise, in this study, the interviewees were not satisfied with the use, results, or guidance in using risk matrices. The focus was too much on the numeric evaluation based on individuals' opinions of the magnitude of the risks.

Based on previous studies, the utilization of risk assessment needs to be developed [4]. Similarly, the interviewees revealed that risk assessment is not fully utilized, for example, in improving an organization's operations or orientating new employees. Finally, in this study, it was found that risk assessment skills need to be further developed and evaluated. Training relating to safety was provided in the companies by various methods. Namian et al. [10] stated that the commitment of the management is one of the important training transfer factors. In this study, the interviewees were quite satisfied with the management's commitment to safety. However, the training should begin at educational institutions to ensure basic knowledge in OHS and risk assessment [18, 19].

Further research is needed to explore how to support the employees' risk assessment skills and how to evaluate the success of the risk assessment process. To determine the objective level of risk, the use and development of risk matrices need to be further studied to decrease the identified difficulties in risk assessment.

The limitations of the study include a limited number of respondents for qualitative interviews as well as a fairly homogeneous research sample. The backgrounds, education, and work experience of the interviewees varied considerably. The responses began to present similar issues. Consequently, saturation was achieved, which indicated that the study had a satisfactory number of interviews.

In addition, the interaction between the researcher and the interviewee may affect the conduct of the interview. The interviewee may feel uncomfortable or the interview may digress from the original topic [20]. These possibilities have been taken into account in the study when designing the interviews. Semi-structured interviews ensured that all topics were discussed. At the same time, it provided an opportunity to discuss more freely and deeply when necessary.

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Experimental Comparison of CWA 17553:2020 Community Face Coverings to Surgical Masks and Filtering Facepiece Respirators

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Abstract. With the worldwide spread of the COVID-19 virus in early 2020, shortages of surgical masks and filtering facepiece respirator (FFR) masks became a critical problem. European governments recommended that civilians should not use these masks so that the shortages in the hospitals would be minimised. In Europe, civilians were instead advised to wear community face coverings. In June 2020, the European Committee for Standardisation (CEN) published CWA 17553:2020 [1–3] which formalised minimum requirements, methods of testing and use of community face coverings. The CWA 17553 is presently only a recommendation, and not an official standard such as the EN14683 standard for surgical masks or the EN149 standard for filtering facepiece respirators. Because there are different performance requirements for these three different classes of masks, it makes comparing their performance challenging. In this work, we perform particulate filtration efficiency measurement, total inward leakage measurement and breathability measurement on a range of surgical masks, filtering facepiece respirators and community face coverings. This analysis provides a useful comparison between material performance and the effectiveness of a mask's design which is manufactured from this material.

Keywords: Community face coverings · Surgical masks · Filtering facepiece respirators

1 Introduction

With the worldwide spread of the COVID-19 virus in early 2020, shortages of surgical masks and filtering facepiece respirator (FFR) masks became a critical problem. European governments recommended that civilians should not use these masks so that the shortages in the hospitals would be minimised. In Europe, civilians were instead advised to wear community face coverings. These community coverings could be made by the civilians themselves or they could be purchased through vendors. In June 2020, the European Committee for Standardisation (CEN) published CWA 17553:2020 which

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formalised minimum requirements, methods of testing and use of community face coverings [2]. The CWA 17553 is presently only a recommendation, and not an official standard such as the EN14683:2019 + AC:2019 standard for surgical masks [3] or the EN149:2001+A1:2009 standard for filtering facepiece respirators [4].

For important performance specifications like material filtration efficiency, the CWA 17553 targets two levels of filtration efficiency; 70% and 90%. Presently, manufacturers of community face coverings can use test results from the ISO/TC 94/SC 15, EN149 or EN14683, even though the size of the challenge particles used in these standards differ by a factor of ten. For example, the EN14683 measures filtration efficiency using bacteria with a size distribution around 3 μm and the EN149 uses NaCl and paraffin oil with size distributions around 0.3 μm. This makes comparisons of the same mask between the different test standards difficult.

In this work, we perform a suit of measurements to compare of community face coverings, with or without external filter inserts, with a range of EN14683-certified surgical masks, both cup-style and folding FFP2 and FFP3-certified respirator masks, KN95-certificated respirator masks, and prototype FFP2 and FFP3 respirator masks certified by the Belgian alternative testing protocol (ATP) [6] for FFP2/FFP3. Tests included total inward leakage (TIL) measured using the PALAS [8] Mas-Q-Check with standard European headform model (the Sheffield head), TIL measured using TSI Portacount instrumentation and human participants, particle filtration efficiency (PFE) measurement using the PALAS Mas-Q-Check, and breathing resistance using a Fluke airflow meter. The work is concluded with a discussion about material selection and how this can be linked to the effectiveness of a mask's design.

2 Comparing Performance Requirements

A standard is a requirement. they provide rules and guidelines for manufactures. in europe these standards are identified with an unique reference code which contain the letters "EN" ("European Standards", 2021). These European standards are approved by one of the three recognized European Standardization Organizations (ESOs): Comité Européen de Normalisation (CEN), Comité Européen de Normalisation Electrotechnique (CENELEC), European Telecommunications Standards Institute (ETSI). We will discuss the standards that are relevant for the medical face masks, ffr and community face coverings (CFCs). This section provides a comparison between the technical performance requirements for the EN149, EN14683 and CWA 17553. The technical requirements for filter performance, total inward leakage and breathing resistance are shown in Tables 1, 2 and 3, respectively.

EN149 Standard

Firstly, FFRs in European countries need to comply with the EN149:2001+ A1:2009 standard [5, 6]. FFRs are classified according to the penetration of filter material and their maximum total inward leakage (TIL). They also need to meet the requirements for the breathing resistance. The EN149 standard divides the FFRs in three classes: FFP1, FFP2 and FFP3. For the penetration test, the filter material is challenged with test aerosols of both NaCl and paraffin oil. The particle size distribution of the NaCl shall be 0.02 μm to 2 μm equivalent aerodynamic diameter with a mass median diameter of 0.6 μm. The total inward leakage (TIL) measures the particulate leakage into the respirator mask. The maximum permissible TIL is the arithmetic mean of leakage measured over a number of exercises for a number of users. The limits are set as: FFP1 = 22%, FFP2 = 8%, FFP3 = 2% (CEN, 2009). Breathing resistance measures the amount of pressure needed to breathe through the material. This is separated by inhalation and exhalation resistance. The maximum permitted inhalation resistance is set by the different classification, for example FFP1, FFP2 and FFP3, and are measured for moderate (30 l/min) and heavy (95 l/min) inhalation rates. The maximum permitted exhalation resistance is uniform across the classifications and measured at a rapid exhalation rate (160 L per minute).

EN14683 Standard

EN14683 standard is a standard that all medical face masks in the European countries need to comply with [5, 6]. These medical face masks are divided in three types: Type I, Type II and Type IIR. An important criteria is the Bacterial filtration efficiency (BFE).The material is tested with living bacteria (Staphylococcus aureus) with the mean size of 3 (± 0.3) μm. Another important criteria is the breathing resistance of the material, described as the differential pressure. The maximum permitted differential pressure is divided again into the three types of medical face masks.

CWA 17553 Guideline

CWA 17553 is a guide that is recommended, but it is not mandatory [6]. This guide has been drafted for community masks. The filtration efficiency of the material is again an important criteria. The material is tested with particles with the size of 3 (± 0.5) μm (NaCl, paraffin oil), with two classified performance levels: Level 70% (greater than or equal to 70%) and level 90% (greater than or equal to 90%). Breathing resistance for the CWA 17553 guideline is equivalent to the inhalation and exhalation performance of the FFP2-class EN149 respirator.

The three standards have different requirements. The Particle Filtration Efficiency (PFE) is a criteria that the EN149 standard and the CWA 17553 have in common. For the EN149 standard they use Penetration of filter material as criteria. With the Penetration of filter material, the PFE can be calculated (Particle Filtration Efficiency (PFE) = 100% - Penetration of filter material). The EN14683 standard uses the Bacterial filtration efficiency (BFE) instead of the PFE. The BFE test uses live bacteria whereas the PFE test uses non-living particles. Beside the difference between the PFE and the BFE, each standard also uses different particle size distributions as reference for the tests. The EN149 standard and the CWA 17553 uses the same particles but they differ in size distribution. For the EN149 standard, the particle size distribution needs be approximately 0.3μm (NaCl, paraffin oil). For the CWA 17553 the particle size distribution needs to be 3 (± 0.5) μm (NaCl, paraffin oil). And the EN14683 standard uses living bacteria with a size distribution of 3 (± 0.3) μm (Staphylococcus aureus).

The Total inward leakage is a criteria that is only included in the EN149 standard. The EN14683 and the CW17553 do not include this in the standards.

The breathability criteria for the three standards are different too. In the EN14683 standard, the flow and whether it applies to the inhalation or exhalation is not specified. For the breathability, the EN149 standard has different flow ratings. For both the EN149 standard and the CWA 17553 there is a distinction between inhalation and exhalation. Each class has a different rating except for the CWA 17553. The CWA 17553 uses

Table 1. Comparison of filtration efficiency between the various classes of European masks

Filtration efficiency	PFE/BFE	Particles/bacteria	Size distribution	Value per class
EN149 standard	PFE	NaCl, paraffin oil (Particles)	0.3 µm	FFP1 = 80% FFP2 = 94% FFP3 = 99%
EN14683 standard	BFE	Staphylococcus aureus (Bacteria)	3 (± 0.3) µm	Type I = 95% Type II = 98% Type IIR = 98%
CWA 17553	PFE	NaCl, paraffin oil (Particles)	3 (± 0.5) µm	Level 70% = 70% Level 90% = 90%

Table 2. Comparison of total inward leakage between the various classes of European masks

Total inward leakage	Value per class
EN149 standard	FFP1 = 22% FFP2 = 8% FFP3 = 2%
EN14683 standard	–
CWA 17553	–

95 l/min as flow and the ratings are the same as that of the FFP2 class from the EN149 standard.

At the time of writing, there is no uniformity in the criteria among these standards and guidelines for the CFCs. These standards use different test variables. This is the reason why it is difficult to compare the masks with each other based on the existing standards. In the following we will try to compare the community face coverings with the medical face mask and FFR masks. For the comparison we will perform uniform test procedures to define the values. This procedure consist of three tests: PFE, TIL and Breathability.

3 Methods and Tested Materials

In this work, we performed three tests. These are the Particle Filtration Efficiency (PFE), Total Inward Leakage (TIL) and the Breathability. The PFE test checks the filter efficiency of the material of the mask. The value of the PFE is expressed in percentage. The higher the percentage; the better the PFE. For the PFE the PALAS Mas-Q-Check is used ("Mas-Q-Check", 2021). The Mas-Q-Check is a particle counting measurement device. This particular model provides a suction with a volume flow of 9.5 l/min. The Mas-Q-Check has two openings. One measures the ambient air and the other measures behind the material. It uses an aerosol spectrometer to measure the particle contamination in the ambient air. Afterwards the device the switches and determines the value of the particle

Table 3. Comparison of breathability between the various classes of European masks

Breathability	Flow	Inhalation per class	Exhalation per class
EN149 standard	30 l/min (Inhalation)	FFP1 = 0.6 mbar	
		FFP2 = 0.7 mbar	
		FFP3 = 1.0 mbar	
	95 l/min (Inhalation)	FFP1 = 2.1 mbar	
		FFP2 = 2.4 mbar	
		FFP3 = 3.0 mbar	
	160 l/min (Exhalation)		FFP1, FFP2, FFP3 = 3.0 mbar
EN14683 standard	Not stated (capable measuring 8 l/min)	Type I = 0.4 mbar/cm^2	Type I = 0.4 mbar/cm^2
		Type II = 0.4 mbar/cm^2	Type II = 0.4 mbar/cm^2
		Type IIR = 0.6 mbar/cm^2	Type IIR = 0.6 mbar/cm^2
		(Not stated for inhalation or exhalation)	(Not stated for inhalation or exhalation)
CWA 17553	95 l/min	level 70% = 2.4mbar	level 70% = 3.0 mbar
		level 90% = 2.4 mbar	level 90% = 3.0 mbar

contamination behind the material of the masks. It can measure particles with sizes from 140 nm to 1 µm. This process is repeated several times. The ratio of the two measured values is used to determine the PFE.

The TIL test checks the inward leakage of the mask. For this test the PALAS Mas-Q-Check is going to be used with a Sheffield head, as shown in Fig. 2. This head is the standard European headform model. The head has two holes. The small hole in the forehead measures the particle contamination in the ambient air. The hole between the lips measures the particle contamination behind the mask. By comparing the two values, the instrument calculates the TIL. The difference between the PFE and the TIL is that the PFE tests the material whereas the TIL tests the seal/mask shape (Fig. 1).

The breathability tests the breathing resistance of the material. The lower the resistance the better. A higher resistance will increase the difficulty to breathe. For this test, a test bench was developed to measure back pressure. The measurement system consists of an AP-50 air pump (VT Velda BV, Belgium), capable of generating a maximum flow of 5.5 l/min, a Fluke 922 Airflow Meter (Fluke Corporation, WA, USA) and a 3D-printed pressure chamber, consisting of adapters for tubes, and foam seat and rigid sealing ring to make an airtight seal with the material under test. This test setup is shown

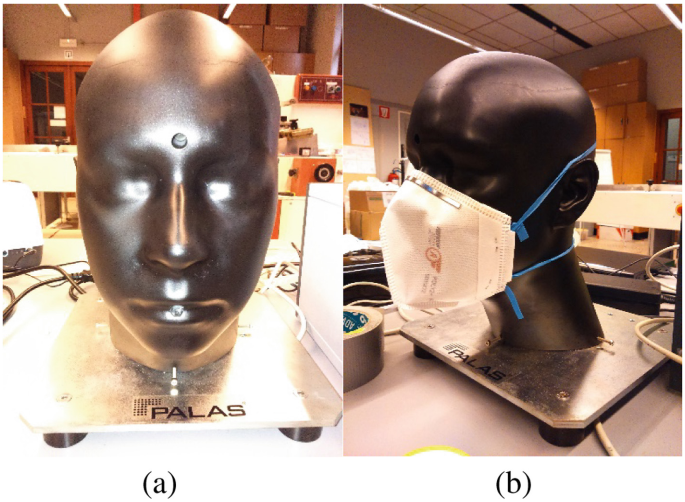

Fig. 1. (a) Sheffield headform used with the PALAS Mas-Q-Check and (B) the headform with a prototype Antwerp Design Factory Poly2+ FFP2 flat-folding respirator on it.

in Fig. 3, where the foam seat is shown in red. The test setups in the EN149, EN14683 and CWA 17553 use pressure drop measurement systems, whereas here we implemented a back pressure measurement system. This makes direct comparison back to an individual standard challenging, however we can use this test setup to benchmark against commercially-available masks that fulfill their respective minimum technical standards for breathability.

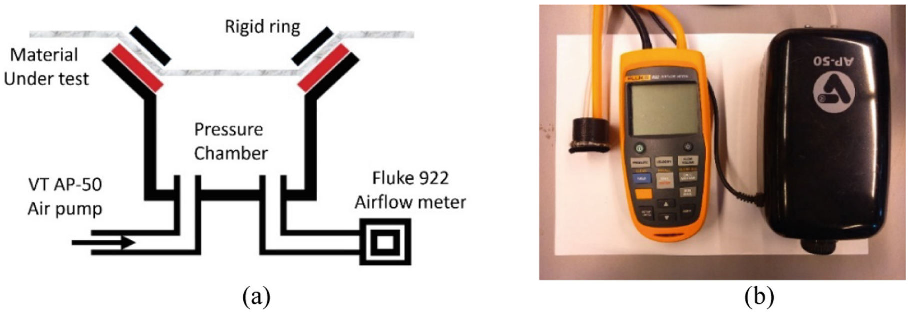

Fig. 2. (a) Cross-section schematic diagram of the back pressure test rig developed to benchmark breathability performance of different mask materials. The thick black line shows the 3D printed pressure chamber, the red line shows the foam sealant which when used with the rigid sealing ring creates an air-tight connection between the pressure chamber and the material under test. (b) Shows a photograph of the hardware.

These tests were performed on a range of commercially-available CFCs, medical face masks and flat-folding and cup-shaped FFRs. In total, ten different types of masks were tested. These are shown in Table 3.

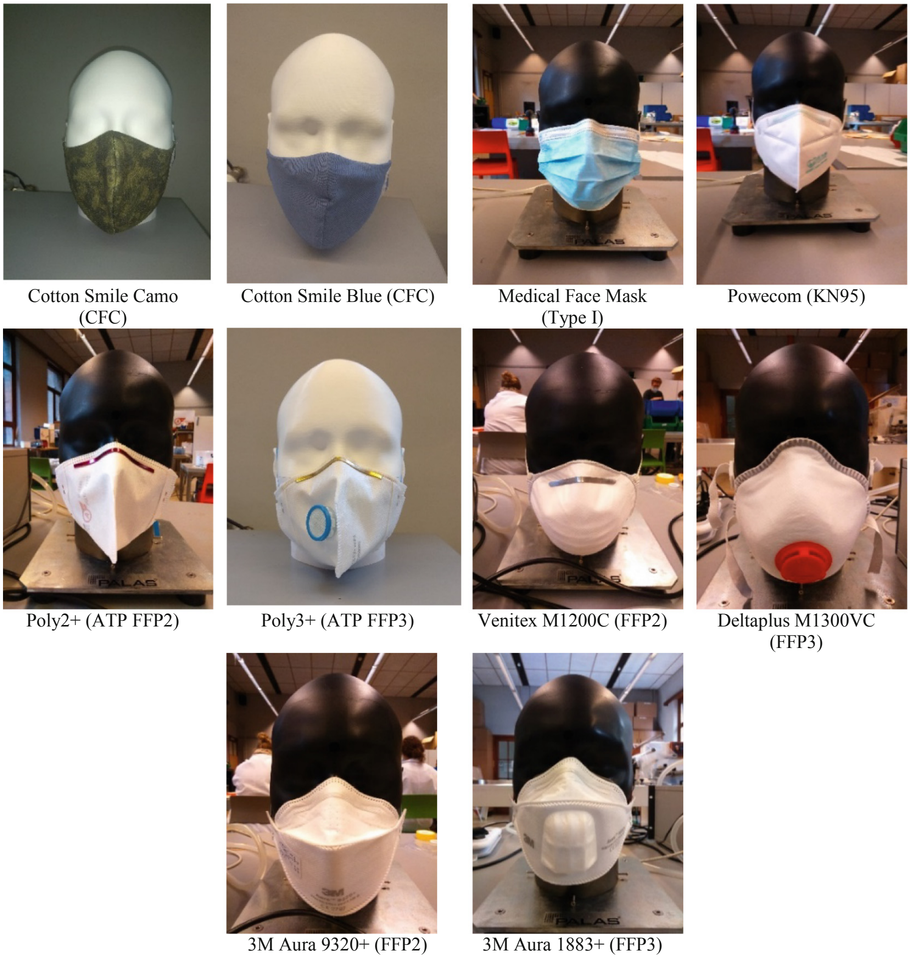

Fig. 3. Ten different community face coverings, medical face masks and filtering facepiece respirators tested in this study

4 Results

Ten masks were tested here, with a CFC-type mask tested with commercially-available activated carbon filter inserts. The values for PFE TIL are measured in percentage. The breathability is measured in Pascal. The results are shown in Table 4.

In the PFE the percentage of the "Cotton Smile camo" and the "Cotton Smile blue", both community face covering, is very low (11.6% and 2.6%, respectively). But when an activate carbon filter is inserted in the community face covering, the PFE increases (98.7% and 97.3%) and it could pass the PFE FFP2 criteria. The PFE from "Surgical mask S1" is lower than the PFE from the community masks with filter. Most of the FFRs passes the PFE test.

Table 4. Comparison of masks under test, their technical standard and class, and PFE, TIL and breathability.

Mask Model	Standard	Class	PFE (%)	TIL (%)	Breathability (Pa)
Cotton Smile camo	CWA 17553	–	11.6	92.5	34
Cotton Smile camo + PM2.5 filter	CWA 17553	–	98.7	86.1	146
Cotton Smile blue	CWA 17553	–	2.6	92.5	20
Cotton Smile blue + PM2.5 filter	CWA 17553	–	97.3	86.3	127
Medical face mask	EN14683	Type I	78.6	83.8	78
Powecom	GB2626-2006	KN95	95.5	71.3	76
Antwerp Design Factory Poly2+	Belgian ATP	FFP2/FFP3	97.3	24.1	129
Venitex M1200C FFP2	EN149	FFP2	96.8	92.1	102
3M Aura 9320+	EN149	FFP2	99.7	19.8	91
Antwerp Design Factory Poly3+	Belgian ATP	FFP2/FFP3	97.0	29.4	118
Deltaplus M1300VC	EN149	FFP3	98.9	74.3	172
3M Aura 1883+	EN149	FFP3	99.9	17.0	126

In the TIL none of the masks passes their according criteria. The FFP2 criteria needs to be at less than 8%. However, the use of a rigid Sheffield headform for TIL measurements is difficult because the smooth surface between the mask and the headform is an unrealistic comparison for a human headform with bone, muscle and skin. Researcher from NIOSH demonstrated an advanced static headform with silicone polymer skin which overcame this limitation [1], however, the data measured here can still be used to compare between masks and use the good-fitting 3M Aura series respirators [7] as a benchmark. Between the FFRs, the "Venitex M1200C FFP2" and the "Deltaplus M1300VC FFP3" masks have one of the worst TIL value. Both of the masks have a cup style shape. The community face covering have a high TIL value even with the filter material.

The value of the breathability increases when the PFE increases. The pressure to breathe in the community masks with filter are slightly higher than that of the FFP2 respirators. The "Venitex M1200C FFP2" and "3M Aura 9320+ FFP2" masks have a PFE of 96.8 and 99.7 % respectively. The value is comparable with that of the community face coverings with filter that have a PFE of 98.7% and 97.3%. However, the "Venitex M1200C FFP2" and "3M Aura 9320+ FFP2" respirators have a breathability of 102 Pa and 91 Pa respectively. The community face coverings with filter have a breathability of 146 Pa and 127 Pa which is higher and thus more difficult to breathe through.

5 Conclusion

Community masks right now do not meet the CWA 17553 requirements. Mainly because of the PFE. The PFE value of the community masks are too low compared to the 70% level mask requirement. A solution for this problem is to insert a filter with a higher PFE in the community mask. This increases the PFE of the community face mask. With the filter it meets the level 90% CWA 17553 mask requirement and even the EN149 FFP2 PFE requirement. In this case the breathability was slightly higher than the FFP2 masks, but these values can only be used as an experimental comparison. Further tests with a more consistent and reliable method must be performed. The TIL is not a requirement for the CWA 17553 but it is nonetheless an important factor. Between the masks that have been tested, the community masks have one of the highest leakages even with the filter. This is a problem because a high TIL means that the air and particles could avoid the mask/filter barrier to enter the ambient environment. The risk of particles entering behind the mask is high.

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Workplace Hazards Difficult to Identify and Manage

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Abstract. Hazard identification (HI) and risk management (RM) are key procedures in occupational safety and health promotion at workplaces. Previous research has reported difficulties in HI and RM at workplaces. To improve the effectiveness of RM, this study charts hazards that are considered difficult to identify or manage at workplaces. Interviews (n = 46) were carried out in four large-scale manufacturing and facility services companies. The interviewees often mentioned psychosocial hazards, hazards due to exceptional circumstances, familiar and obvious hazards, and hazards of the shared workplaces as difficult to identify or manage. The reasons these hazards were difficult to identify or manage varied from lack of knowledge and competence to problems in communication and safety culture. Certain hazards receive less attention than they should because they were considered difficult to deal with. Further studies on the successful measures to manage these risks are needed.

Keywords: Hazard identification · Occupational safety and health · Risk assessment · Risk management · Workplace safety

1 Introduction

As a part of the risk management (RM) process, hazard identification (HI) and risk assessment (RA) are key procedures in managing occupational safety and health (OSH) at workplaces. In Finland, the Risk Assessment in Workplaces Workbook [1], published by the Ministry of Social Affairs and Health, provides guidance for carrying out OSH-related RA and is widely applied in workplaces. However, the workbook contains more detailed guidelines concerning some RM areas than others. For example, the implementation of risk controls and the utilization of RA results are covered less comprehensively than HI [1].

In previous research, difficulties in identifying hazards and the utilization of RA results in OSH management have been reported. Some studies have reported that a considerable number of hazards remain unidentified [2–3]. Poor hazard recognition is often reported as one of the major reasons for accidents [4]. Previous research has also suggested that some hazards (e.g., trivial hazards, emerging hazards, and hidden hazards)

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are more difficult to identify than others (e.g., obvious hazards) [3]. Moreover, there is usually subjectivity in HI and RA. Inadequate HI hinders proper hazard management [5].

The recent OSH promotion activities have not had desired results in Finland and only slightly decreased development can be seen in accident statistics [6]. To ensure favorable progress, a better understanding of the problems encountered by workplaces while carrying out HI and RM is needed. The aim of this study was to chart the kinds of hazards that are considered difficult to identify or manage in workplaces. We discuss some reasons for the difficulty in identifying or managing these hazards.

2 Materials and Methods

The objectives of this study were explorative and descriptive in nature. Hence, a qualitative approach [7] and a case study [8] were employed as a research strategy. Consistent with the methodological approach, data for this study were collected with interviews from four case companies that participated in the study.

The participating companies were all large-scale companies. The revenue of the companies varied between 70 and 420 million Euros, and the number of personnel was between 250 and 7900 persons at the time of the study. Three of the companies were from the manufacturing industry and one from the facility services industry. The companies were chosen based on their concrete need and interest to develop their risk management practices. All the companies were part of an international or larger Finnish corporation. However, the study focused on Finnish operations and on manufacturing companies in one factory or production facility. The RM practices of the companies were based on the Risk Assessment in Workplaces Workbook [1], published by the Ministry of Social Affairs and Health. The Workbook provides basic guidelines in OSH-related RM for workplaces, and it is widely applied in Finland. The implementation of the Workbook at the companies was described in more detail in Nenonen et al.'s study [9].

The data for the study was collected by interviewing personnel involved in RM at the participating companies. A total of 46 interviews were carried out, and 56 persons were interviewed between March and May 2017. The details of the interviews and interviewees' background are summarized in Table 1. The interviews were directed at personnel involved in RA. The selection of the interviewees was conducted with the companies' contact persons, such that the interviewees had varied but at least some RA experience.

The interviews were semi-structured. The themes and questions were considered in advance, but the order and form of the questions could vary, and additional questions were asked as needed. In addition, the questions varied according to the background of the interviewee. The interview questions were drawn up based on initial meetings with the companies, research questions, and the steps involved in the risk management process. The purpose of the interviews was to find out how risk assessment and management were being practiced, and what good practices and development needs relating to RA have been identified by those who participate in RA. The interview questions included, for example, questions such as: What kind of OSH-related hazards are there at your company? Are some hazards difficult to identify or manage? Do some hazards receive

Table 1. Background information of the interviews (n = 46) and interviewees (n = 56).

Interviews per company	Company A (35%), Company B (22%), Company C (22%), Company D (22%)
Percentage of interviewees	Company A (34%), Company B (18%), Company C (29%), Company D (20%)
Interview medium	Face-to-face interviews (63%), phone and Skype interviews (37%)
Interview type	Individual interviews (80%), group interviews (20%)
Duration of the interviews	Average 48 min, range 23–86 min
Role of the interviewees	Manager or supervisor (27%), OHS representative (27%), employee (21%), HS or HR manager or specialist (16%), occupational health service representative (9%)

less attention than others? Which hazards and why? Which hazards are easy to identify and why? All interviews were recorded and transcribed. The results of the interviews were categorized according to the themes that emerged.

3 Results

The interviewees indicated that hazards that need attention often and concrete and visible hazards were easiest to identify. These hazards included, particularly, accident hazards and physical hazards, such as hazards related to noise, temperature, and lightning. The interviewees gave such examples as slipperiness, hazards related to stairs and moving machines, visible risk of falling from high and deficiencies in protective equipment. Some interviewees mentioned that hazards related to chemicals were easy to identify.

The interviewees mentioned several types and examples of hazards they perceived as difficult to identify or manage. Table 2 provides a summary of these hazard types with examples. The interviewees often mentioned hazards that are difficult to perceive by senses, psychosocial hazards, hazards that are related to the way work is carried out, and hazards that are familiar and obvious or are considered part of the work. As hazards that are difficult to identify, the interviewees emphasized, particularly, hazards due to exceptional circumstances, hazards of the shared workplaces, hazards that are related to the way work is carried out (e.g., not following safe work procedures), and hazards related to changes in the work environment. Psychosocial hazards were considered both difficult to identify and manage.

Many of the hazards mentioned in the interviews had been recognized in the companies at some level. However, the interviewees pointed out that some of these hazards (e.g., hazards related to chemicals) should be more actively recognized and realized in day-to-day operations. Other hazards that often received less attention included familiar and obvious hazards, hazards that were perceived as minor, and hazards for which prevention or control measures were difficult to devise. A couple of the interviewees were of the opinion that all hazards could be identified, or they could not name any hazards that would be difficult to identify or manage.

Table 2. Hazards difficult to identify or manage or being given less attention.

Category	Examples
Psychosocial hazards	Feeling of inadequacy, bullying, harassment
Hazards related to exceptional situations	Machine or production line malfunctions
Familiar and obvious hazards	Slipping and stumbling, going up and down on the stairs, forklift traffic
Hazards at the shared workplaces	Processes, chemicals and machines used by other parties operating at the shared workplace
Hazards considered as part of the work	Minor faults in equipment, work assignments with no previous requirements for protective equipment
Hazards related to changes in the work environment	New machines, removed stairs, new gap or shaft
Hazards related to the way work is actually carried out	Not following safe working procedures when in a hurry
Hazards that are difficult to manage	Lone working in the nighttime, traffic, lack of space, coping with work
Joint effects of different hazards	Joint effects of different chemicals and substances, the impact of haste or fatigue on working methods in exceptional situations
Hazards that are difficult to perceive by senses	Chemicals, gases, mold, dust
Hazard with related risk perceived to be minor	Moving around on the stairs, using ladders, poor working postures
Other hazards	Work tasks carried out occasionally, slips when using tools

Lack of knowledge and competence were often mentioned as a reason why some hazards were difficult to identify and manage. In particular, hazards that are difficult to perceive with senses, psychosocial hazards, hazards that are perceived as minor hazards, and hazards related to exceptional situations or changes in the working environment were mentioned with regards to knowledge and competence. For example, the identification and management of hazards related to chemicals require previous knowledge about their properties. Further, some personnel were not always aware of what psychosocial hazards are or that poor ergonomics could cause health problems (because the problems may not rise immediately), and that these issues should be reported. Moreover, the interviewees pointed out that previous work and RA experience can help to recognize, for example, risks related to new machines and possible malfunctions. The interviewees also mentioned that it was difficult to think of hazards related to exceptional situations and that they may lack knowledge of how these situations proceed if they have not occurred previously.

Moreover, the interviewees emphasized the role of communications and safety culture in successful hazard identification and management. They mentioned that it was sometimes difficult to obtain information about psychosocial hazards and hazards that are related to the way work is carried out in practice. The interviewees further explained that people were not always willing to inform others about psychosocial issues or if safe working methods were not followed, or sometimes they were not even aware that these issues should and could be reported. These issues might be more easily reported in an anonymous questionnaire or confidential discussion with occupational health personnel than in a face-to-face RA situation. The identification of the hazards in the shared workplaces is difficult because of the challenge in obtaining all necessary information about all processes and operations going on in these premises. With regards to the safety culture, the interviewees also indicated that there could be resistance in using personal protective equipment (PPE) if the hazard is familiar and the PPEs were not previously required in the same work assignment. Moreover, particularly small changes (e.g., removed stairs) in the work environment are easily missed when in a hurry and if the culture of the workplace nourishes the idea of quick results over safety.

4 Discussion

The fact that the interviewees were able to recognize problems in hazard identification and management indicates that there was RM competence at the workplaces in this study and that these issues were considered, and the workplaces were willing to develop their RM practices. However, the results also showed that the identification and management of several types of hazards were considered challenging by these workplaces. Moreover, certain hazards received less attention than they should because they were considered difficult to identify and manage.

In congruence with previous studies, it was found that hazards related to psychosocial risks [10], hazards that are difficult to perceive by senses [10], hazards of the shared workplaces, hazards related to changes in the work environment [11], and hazards related to the way the work actually is performed (compared to how it is instructed to be carried out) [12, 13] were considered difficult to identify or manage. The increased importance of and general attention to psychosocial hazards and related risks [14] can be seen in the results of this study, as exemplified by the heightened mention of this hazard category in the companies that participated in this study. Nevertheless, the interviewees felt they lacked the expertise to be able to deal with these issues. A great deal of attention was paid to hazards typical of the manufacturing and facility services industries and reduction of associated risks in the companies. Nevertheless, many of these hazards were still regarded as difficult (e.g., new machines, machine malfunctions) or requiring more attention (e.g., chemicals). RM is an ongoing project, and even familiar hazards require continuous attention.

The reasons why these hazards were difficult to identify or manage varied from lack of knowledge and competence to problems in communications and safety culture. Previous studies have suggested that training can improve the identification of hazards [2, 3, 11, 15]. Successful identification and management of hazards require competence and cooperation. Some studies have discussed limitations in coverage, generalizability, and dynamism of hazard recognition methods, which can hinder the success of HI.

This study has some limitations, including collecting data from only four companies that represented manufacturing and facility services industries. Further studies are needed to discover possible similarities and differences in HI and management among different industries. Moreover, the results of this study are based on the perceptions of those involved in the HI and RM at the workplaces surveyed. The findings from this study could be further verified using, for example, data, and documents related to RM and accidents occurring at the workplaces. Nevertheless, more information is still needed on the successful measures to manage risks receiving inadequate attention to improve the effectiveness of the RM process.

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COVID-19 Prevention in Construction Sites: A Case Study in a Railway Project

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Abstract. The COVID-19 pandemic demands additional measures from organizations. This is particularly challenging for construction sites where it is already difficult to apply any sort of preventive measures under normal circumstances. This study aimed at recommending measures to prevent the transmission of the Coronavirus in a construction site. The Plan-Do-Check-Act cycle was followed to improve the efficiency and effectiveness of the intervention. The current scientific knowledge about the COVID-19 disease as well as the legal requirements on this subject were taken into account. The Job Safety Analysis method was applied to assess the risk factors of transmission of the Coronavirus on 46 daily job tasks and proved to be a suitable method for it. However, some of the legal requirements were found difficult to apply in the construction sector. The way a set of tasks is performed needs to be reconsidered to raise awareness on COVID-19 among employees in the construction environment.

Keywords: Construction industry · Coronavirus · SARS-CoV-2 · PDCA · Job safety analysis · Risk assessment · Prevention

1 Introduction

The first confirmed case of COVID-19 to happen in Portugal occurred on March the 2nd of 2020 and a few days later, on the 11th, the WHO declared COVID-19 as a pandemic.

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The disease is caused by the SARS-CoV-2 virus, which mainly spreads in small liquid particles when the infected person coughs, sneezes, speaks or breathes heavily and is in close contact with other people or different types of surfaces. The virus can get directly into people's mouth, nose or eyes, or when they touch these body regions without having cleaned their hands first, after touching contaminated surfaces. Transmission occurs particularly in indoor, crowded and inadequately ventilated spaces. Nevertheless, transmission may also occur outdoor, especially when people are close to each other and share objects. Moreover, even asymptomatic but infected people can be contagious [1].

According to WHO [2], until 26 January 2021 there have been around 99 million confirmed cases of COVID-19, including 2.1 million deaths, worldwide. By that same day 6.53×10^5 people have been infected and 1.1×10^4 have died from this disease in Portugal [3].

This is no longer exclusively a public health issue and occupational settings other than those where health care is provided are now facing an additional emergent biological risk factor. Consequently, economic and social disruption threatens the long-term livelihoods and wellbeing of millions.

The COVID-19 pandemic has had a significant impact on the construction sector, which is sensitive to economic cycles. Still, construction holds much potential to stimulate recovery, thanks to its potential to create jobs. However, it is known that working conditions in both mobile and temporary construction sites are poor. A recent report [4] showed that 8 390,9 accidents per 100 000 workers occurred solely in the Construction sector in Portugal, in 2018.

The Decree-Law 273/2003 of 29 October [5] establishes general rules of planning, organization and coordination to promote occupational safety and health (OSH) in construction sites. The Health and Safety Plan (HSP) is one of the fundamental instruments for planning and organizing safety on temporary and mobile work sites, taking into account the general principles of prevention of occupational risks. Throughout the construction phase of the project, the HSP must be monitored and updated whenever working methods, materials or equipment are modified, unforeseen constraints are identified, new hazards appear or opportunities to improve are revealed.

The construction sector keeps producing, and safe and healthy conditions must be continuously provided to workers. Therefore, this study aims at thoroughly checking all tasks performed in a construction site and how OSH is managed in order to identify situations where the risk of SARS-Cov-2 transmission exists and suggest the implementation of control measures according to the most up-to-date scientific knowledge, standards and guidelines directed for the occupational context.

2 Methods

2.1 The Construction Site

We have focused on a project aiming at rehabilitating the railway branch of one of the main seaports of Portugal. The construction phase took place between November 2019 and July 2020, but the study only started in April, when it was at 49% of the planned, and ran until the yard was demobilized in August.

The work covered an approximate length of 2,000 m, and an informal division of the area was adopted on two fronts. Front 1 refers to the area whose access is adjacent to the main entrance to the railway terminal and where the social yard and material park were installed. Front 2 corresponds to the other end of the area which was accessed via the main local road.

Work was planned to be done between Monday to Friday, from 8:00 AM to 5:00 PM. Whenever interdiction of railway circulation or the catenary blackout were required, interventions were programed to happen on weekends or during the night.

One hundred and sixty-three workers (99% male) from twenty companies worked at the construction site. Drivers were the most prevalent professionals (23%) due to the regular use of mobile equipment to move large amounts of land and materials. Construction (20%) and railway officers (9%), servants (18%), catenary officers (7%) and electricians (4%) were also among the workforce. There were also a OSH technician (OSHT) and an OSH coordinator (OSHC). The number of workers simultaneous present at the yard increased progressively as the work advanced without exceeding 95. Although most workers (79%) were aged between 30 and 59, there were eleven above 60 years old. The majority (94%) were from Portuguese speaking countries and 83% relied on the accommodation provided because they lived far from the yard and only went home on weekends.

2.2 Plan-Do-Check-Act Cycle

The Plan-Do-Check-Act (PDCA) Cycle is an iterative method particularly used in the scope of Quality Management Systems regarding process and product control. It has proven to be useful to promote continuous improvement and has been used in other contexts, namely that of Occupational Health and Safety Management Systems [6].

It may be applied at different levels within an organization to solve problems based on both qualitative and quantitative data, namely while managing risks associated to a particular activity [7, 8]. Due to its characteristics, coverage and applicability, when dealing with the SARS-Cov-2 transmission risk in the construction site analyzed in this study we adopted the PDCA approach after adapting Campos flowchart [9].

2.3 Job Safety Analysis

Job Safety Analysis (JSA) is a qualitative risk assessment method that systematically and progressively considers all risks related to specific job tasks in order to support decisions on selecting and implementing countermeasures to make the work activity safe. Worker participation provides in depth knowledge about the practices regarding the job and contributes to minimize the likelihood of missing hazards as well as to promote the ownership of the proposed countermeasures. JSA is particularly recommended for situations where hazards are present and not adequately controlled by existing work procedures or barriers, activities require deviation from work prescribed by procedures or routines, the teams of workers are not familiar with each other and preconditions, such as weather conditions, time schedule and parallel operations, change [10, 11]. Basically, work activity is broken down into tasks and subtasks, depending on the level of detail required, and task-specific hazard insight is pursued (potential events and conditions leading to dangerous situations, as well as potential consequences of each hazard and expected frequency of occurrence are identified) so that risk reduction measures may be proposed and implemented for each task/subtask.

Like in any type of project, most risks should be mitigated as early as possible in a construction project's life span. Ideally risk should be reduced during the client, designer and contractor's planning and design processes, leaving only residual risks to be handled during the construction phase. For the above-mentioned reasons, JSA is considered appropriate for dealing with this residual risk and was used to deal with the new coronavirus in this particular construction site.

JSA was accomplished with a few adjustments:

1. Instead of breaking down the tasks we have identified their main characteristics due to the dynamics of the execution of most of the work and the relevance of understanding the interactions between workers, equipment, tools and the environment.
2. We have focused on the identification of the risk factors for the coronavirus transmission and not on all existing hazards because these had been previously identified and were not relevant for this study.

Particular attention was given to the operations involving mobile and railway equipment. The registration sheet proposed by the Harvard University [12] was adapted to the specificities of our study and the requirements of the analyzed construction project.

2.4 Documental Research and Free Observations

To complete this study, relevant data was sought and sorted from different sources. One of the most valuable was the construction project's HSP, which was particularly helpful for the risk assessment. National legislation, standards and guidelines published by WHO and the National Health Authority (NHA) dealing with COVID-19 and the SARS-Cov-2 virus transmission were the basis for the control measures' establishment. Emphasis should be put on a specific document published in Portugal which establishes the requirements for preventing and controlling the infection by the coronavirus within the construction industry [13].

An in-depth knowledge of the working conditions, operating modes, supporting activities, interfaces between the stakeholders and the work progress in the yard was acquired via inspections, activity monitorization and informal conversations with the workers. All teams and particularities of work were covered, namely additional risks when work is done during the night and on weekends or requires railway circulation interdiction or cutting off catenary power, which pose temporal pressure to reestablish normal operation conditions.

3 Results and Discussion

From the forty-six tasks submitted to a JSA, ten were classified as critical (Table 1) due to the proximity of workers, not being possible to provide a safe distance between them: eight implied the simultaneous presence of two workers on the lifting platform and two were related to the placement of the rail on the sleepers, which is carried out manually by a group of workers.

Eighteen task/workstation characteristics (Table 2) were identified as relevant and ten risk factors (Table 3) were found to play a significant role in the new coronavirus transmission in the construction site.

Based on the identified risk factors, the Portuguese legislation, NHA and WHO guidelines, twenty-three recommendations were produced to prevent spreading the virus among the construction workers (Table 4).

Table 1. Critical tasks identified during the JSA.

Critical tasks for the transmission of SARS-Cov-2	
• Dismantling/settlement of the railroad	• Rail replacement
• Disassembly/placement of railway earthing systems	• Disassembly/assembly and adjustment of cantilever
• Ripping/release of catenary cables	• Assembly of dropper
• Assembly of electrical equipment	• Catenary regulation, execution of shunts and electrical connections
• Assembly of anti-slip system	• Alteration/placement of catenary flexible suspension

To ensure the implementation of the preventive measures' effectiveness, a monitoring plan was suggested and recording sheets were prepared (Table 5).

It was possible to verify that the Portuguese legislation and the guidelines provided by the NHA concerning the prevention of COVID-19 are in tone with the current scientific knowledge about the disease. However, the HSP analysis revealed the need of an in-depth review of the document and twenty-nine recommendations were made for 12 of the 30 chapters integrating the document.

Overall, most tasks were done by specific and cohesive teams which may have limited the close contact with each other. Lunch time, accommodation and transport from, to and within the construction site were also organized taking this into account. However, this fact may have induced the workers' failure to comply the disease prevention measures within each team. Training and raising the workers awareness regarding the virus transmission and the preventive measures will definitely make them adopt an adequate behavior.

Table 2. Relevant aspects of the tasks identified throughout the JSA.

Relevant characteristics	
• Indoor spaces: offices, meeting rooms, material containers, vehicles, mobile and railway equipment	• Need to extend daily working hours due to scarcity of HR and equipment and comply with the planned schedule
• Vehicles to move workers between work fronts as well as between accommodation and the construction site	• Operation of mobile and railway equipment by specific drivers with non-significant turnover between drivers and equipment
• Mostly outdoor activity	• Shared use of tools in most situations
• Individual and shared offices (2 or more people)	• Some tasks performed by specialized and small cohesive teams, with non-significant turnover
• Several undifferentiated workers helping different teams	• Many tasks are simultaneously done by two or more workers
• Use of portable and light equipment	• Manual and mechanical material handling
• Existence of a general work plan and a fortnight plan revised every week used by the OSH officer to release work permits	• Participation of external workers in tasks such as mobilization of the yard, waste, material and equipment transportation
• Workers are directed to daily tasks by supervisors and team leaders	• Work at height using a lifting platform by one or two workers
• Work requiring the interdiction of the railway or catenary power-off are done at night and during the weekend	• Mechanized activities on the railway but also demanding manual work performed by a group of workers

Table 3. Risk factors for coronavirus transmission identified throughout the JSA.

Risk factors for the transmission of SARS-Cov-2	
• Air transmission when two workers are simultaneously on the lifting platform	• Air transmission when more than one worker travels in the same vehicle
• Supervisors lack of attention to COVID-19 preventive measures when distributing daily activities to workers	• Risk analysis failure leading to Work Permit neglecting the biological risk or not considering PPE compatibility
• Worker's lack of attention to comply with COVID-19 prevention measures	• Scarcity of resources and the need to meet work schedule and road blocking periods
• Air transmission when a safe distance of at least 2 m separating workers is not feasible	• Activity planning failure compromising the implementation of COVID-19 prevention guidelines
• Physical contact between workers	• Contact with contaminated surfaces (door handles, materials, tools, etc.)

Table 4. Recommendations derived from JSA to prevent coronavirus transmission in the yard.

Recommendations to prevent SARS-Cov-2 transmission	
• Promote teleworking whenever possible	• Organize shared offices' layout to guarantee a safe distance between workers
• Prioritize task completion by a single worker when possible	• Organize activities to ensure a 2 m safe distance between workers
• Reduce spaces capacity to avoid crowding	• Restrict operators' access to mobile and railway equipment cabins
• Ensure cleaning and maintenance of AC units and promote mechanical ventilation when using them	• Avoid holding face-to-face meetings in closed spaces, preferring digital or telecommunication means
• Reduce vehicle capacity to two thirds	• Shared vehicles use by team members only
• Avoid material sharing	• Prioritize natural ventilation
• Wash hands with water and soap or ABAS* several times a day and whenever handling shared objects	• Reinforce the availability of ABAS* when provision of washbasins nearby is not possible
• Install chemical toilets with washbasins at the site entrance while mobilizing and demobilizing the yard	• Apply antiviral disinfectant on tools and surfaces regularly touched
• Wear mask in shared offices, meeting rooms, common areas, when travelling in the same vehicle and in activities requiring the presence of more than one worker	• For activities already requiring the use of mask, ensure that it is compatible with the biological risk
• Make sure external workers are aware and apply the yard's COVID-19 preventive measures	• Reassess the Work Plan in order to identify the need to update the preventive measures
• Provide training to supervisors and team leaders to ensure workers comply with COVID-19 preventive measures put in place	• Promote the participation of supervisors and safety technicians in the fortnightly Planning and its weekly update to minimize the risk of the virus transmission
• Night and weekend activities monitoring by safety technicians	*ABAS – Alcohol-based antiseptic solution

Recommendations form the NHA such as cleaning workspaces with resources that are scarce in the yard, namely hot water, and using different workers to clean each type of installation were found difficult to implement in the construction site.

Table 5. COVID-19 preventive measures' monitorization plan.

What to monitor	Frequency	Control means	Documents	Responsibility
Recommendations for the Construction sector from the NHA	Monthly	· Visual · Documental	· NHA guidelines · Contingency Plan · Training records · Cleaning records · Yard access control records	· OSHT · OSHC
Site's Contingency Plan	Monthly	· Visual · Documental	· NHA guidelines · Contingency Plan · Training records	· OSHT · OSHC
General COVID-19 preventive measures	Monthly	· Visual · Documental	· Workers' records · COVID-19 related incidents	· OSHT · OSHC
JSA recommendations	Daily	· Visual	· JSA records	· OSHT · OSHC

4 Conclusions

The main goal of this study was to identify risk factors for the transmission of COVID-19 among construction workers and suggest preventive measures to be put in force within the construction site.

Good news is that there wasn't any infected worker in this particular yard throughout the construction phase of the project. Nevertheless, it can't be concluded that there was no risk of transmission of the virus.

Although safety culture had not been investigated in this study, differences between contractors regarding the availability of the necessary resources and the respective workers behavior were noticeable. Training and information provision are crucial to raise awareness among workers on the disease and the virus transmission and increase preventive measures compliance.

The adoption of the PDCA approach allowed to reduce the probability of omitting relevant facts in the analysis and the recommendation of measures to prevent the disease, ending with the proposal of a monitoring plan in compliance with the Check phase.

The JSA was a valuable tool in identifying the risk factors for transmission of the coronavirus within the construction site, complementing data that had been previously collected and included in the HSP.

In a pandemic context characterized by too many uncertainties, updating knowledge, monitoring, reassessing the implemented measures and improving them is determinant to achieve the goal of preventing the disease.

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Risk Analysis Based on ETA, FTA and Bowtie Methodologies for the Bulk Coal Discharge Process

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Abstract. A safety analysis was performed to determine possible causes of coal falling in the bulk coal discharge process using a methodology for risk analysis based on a combination of Fault tree analysis (FTA), event tree analysis (ETA) and BowTie (BT). The steps for risk assessment were the following: Description bulk coal discharge process, Event sequence modeling where logic models (ETA; FTA; BT) and Consequence assessment. The bulk coal discharge process is performed using cranes which are deployed in the terminal, in parallel to the coal holds of the ship. The hydraulic grabs descend onto the ship holds at an angle, determined by considerations of wind direction and intensity, which shovel up the coal and lift it upwards. The grabs move along the crane handle, and open up above the funnel which pours the coal into the coal conveyor, this procedure is repeated sequentially until empty the ship. Results from BT allow to identify three possible causes of coal falling. Two of which are attributed to technical factors such as crane failure and grab failure, while the other cause is related to human factors such as lack operational discipline (OD). Three barriers were identified to prevent the fall of coal: certified crane, hermetic grabs and operational discipline. Two mitigating barriers were identified: Vacuum truck to clean the coal in the pier and tablecloth to avoid coal fall in the sea. Finally, the consequences if not working barriers are: coal built up on pier and sea pollution. However, it can't be ensured that the stranding of coal on the beaches is directly caused by port operations.

Keywords: Fault Tree Analysis (FTA) · Event Tree analysis (ETA) · Bow tie (BT) · Bulk coal discharge

1 Introduction

The identification of hazards is an important aspect of the risk assessment process because, if the hazards are identified, the risks with them can be assessed [1]. Risk analysis is an important activity to ensure that critical process [2], like bulk coal discharge, operate in a safe and reliable way. Fault tree analysis (FTA) is one of the most techniques, used by a wide range of industries. Fault tree is a graphical method commonly used in both reliability engineering and safety management [3].

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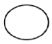
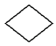
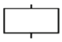
Bell Telephone Laboratories developed the FTA concept in 1961 for used by the U.S. Air force with its Minutemen system [4]. FTA starts by identifying an undesirable event, called "top event". Fault events that can cause its occurrence (i.e., the top event) are connected by logic operators, such as OR and AND [5] (Table 1).

Table 1. Symbols used in fault trees [6].

Symbol	Meaning	Description
	Logic gate AND	The output event happens only if all input events happen
	Logic gate OR	The output event occurs if any of the input events happen
	Basic event	Failure of a component that has no identifiable primary cause. It is the highest level of detail in the tree
	Undeveloped event	Failure of a component with a primary cause undeveloped because of lack of information
	Intermediate event	A fault event that occurs because of one or more antecedents causes acting through logic gates

FTA can be used qualitatively to identify potential causes and the ways in which failure (the top event) occurs [7] or quantitatively to calculate the probability of occurrence [8]. The probability of the top event is determined by combinations of faults, with Boolean algebra used to quantify each fault's probabilities [9]. In a graphical way, the various combinations of equipment faults and failures that can result in the accident event are displayed [10].

Event tree analysis (ETA) is used to describe the logical connection between the potential successes and failures of defined safety systems or safety functions as they respond to the initiating event and the sequence of events [11]. The conventions used in ETA are: events proceed from left to right on the page; The upper branch identifies that the defined action occurs (Success) and the lower branch identifies that the action does not occur (failure) [1]. ETA takes the structure of forward (Bottom up) symbol logic modeling technique and ended in the consequences [12].

ETA is an inductive procedure that shows all possible outcomes resulting from an accidental (initiating) event, taking into account whether installed safety barriers (SB) are functioning or not, and additional events and factors [13]. The initiating event corresponds to the starting point of the event tree and the sequence of events that can lead to different possible outcomes [14]. ETA is commonly used as a preferred option in understanding, analyzing and communicating safety risk [15].

The use of FTA and ETA techniques leads to a detailed analysis of the hazards and theirs causes, thus improving the safety systems [16]. FTA is used to describe the causes of an undesired event. ETA shows the consequences [17]. ETA and FTA are very useful tools for risk assessment [18]. Since bow-tie (integration of FTA and ETA) is a structured and systematic methodology to predict risk [19].

Central in bow-tie model is an event (incident) that has a certain probability of occurrence. Each incident has different causes and effects, which are indicated to the left

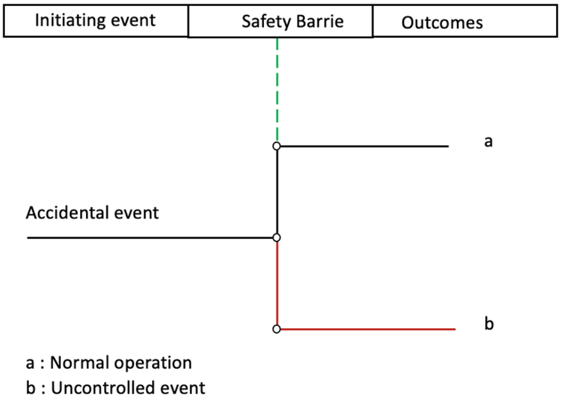


Fig. 1. Event tree for an operation with only one SB, when the SB is not working the outcomes is uncontrolled event.

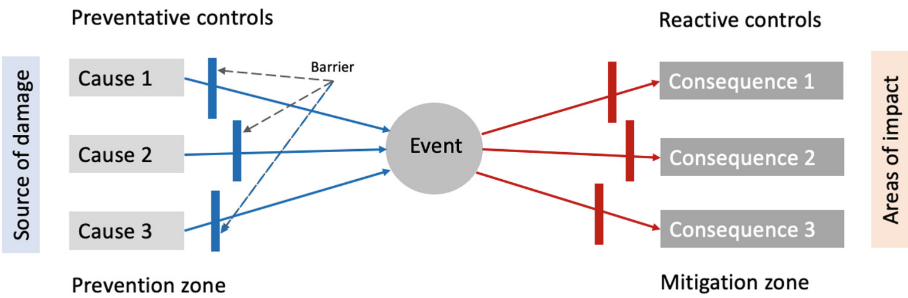


Fig. 2. Bow-tie model used for the risk assessment.

and right of the bow-tie (BT), respectively. The causes (Prevention zone: left side of BT, Fig. 2) are events that may lead to effects (Mitigation zone: right side of BT, Fig. 2) that are the consequences [20]. However, application of the BT to maritime risk assessment is relatively rare due to the lack of data acquisition [21]. Risk mitigation measures can be recommended based on the risk assessment for each procedure performed on bulk coal discharge process.

The human error is critically important, however, the quantification of human error is quite difficult due to data scarcity in records [22], according to the statistics is the most contributory factor to safety system failure and accident [23]. The consequence of human error may pose acute hazards to human life, the ocean environment and property [24]. Finally, when process safety depends largely on human factors, operational discipline takes great importance [25]. Operational discipline can be defined as a commitment and dedication to perform each task in a right way, each time and shows strength of safety culture [26].

2 The Case Study

The case study considers the coal discharge process that typically occurs in the different coal ports of the world. The coal is an organic and combustible sedimentary rock of black or browing-black color with a high carbon content and varied physical, chemical and technological properties [27]. Spontaneous combustion of coal is a complex physico-chemical process [28], furthermore, in the case where dust concentration reaches certain level, explosion could occur, causing devastating damage to the equipment [29], but this paper focuses exclusively on the coal discharged process.

The ship is secured and anchored close to the discharge platform, and the crew stabilizes it during the discharge process. In some countries, discharge is performed at sea, and coal is transported from the ship onto barges, and from there to the coal conveyor.

The discharge process is performed using cranes which are deployed in the terminal, in parallel to the coal holds of the ship, and which move on transport wheels.

The bulk coal discharge process is performed using cranes which are deployed in the terminal, in parallel to the coal holds of the ship. The hydraulic grabs descend onto the ship holds at an angle, determined by considerations of wind direction and intensity, which shovel up the coal and lift it upwards. The grabs move along the crane handle, and open up above the funnel which pours the coal into the coal conveyor, this procedure is repeated sequentially until empty the ship.

Discharging is a complex, for this reason, the discharge process is carried out in a balanced and gradual mode between the holds and in full cooperation between the ship's crew and crane operators. Bulk carriers lose some of their weight after discharge, rising a few meters above sea level. When three discharge quayside cranes work simultaneously, the discharge process is completed in approximately 4–5 days, in the case of a cape bulk carrier, or in 2–3 days, in the case of a Panamax ship.

3 Results

The generic controls or barriers directly related to the coal discharge process are: certified cranes, hermetic closing grab and "tablecloths" that prevent the coal fall in the sea.

Table 2. Potential basic events which cause top event "Coal fall".

Basic events	Basic event (BE) no.
Grab failure	BE1
Lack Maintenance	BE2
Operator make an error of judgement	BE3
Poor training operators	BE4

In the analysis of coal discharge process, the fault and event trees describe not only mechanical failures, but also operator's front line errors. The major causes of coal fall at the sea are illustrated in Table 2. The faults and relationships for intermediate event have been identified and a logical combination of incidents has been deduced that can trigger unwanted event: "coal fall at the sea" (Fig. 3).

Figure 4 shows the events that together led to the pollution sea and the built up coal in the pier. The tablecloth extended along the ship prevents pollution sea with bulk coal.

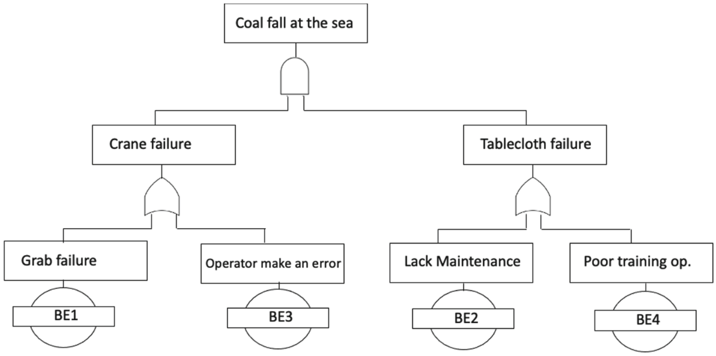


Fig. 3. Fail tree analysis used for coal discharge process

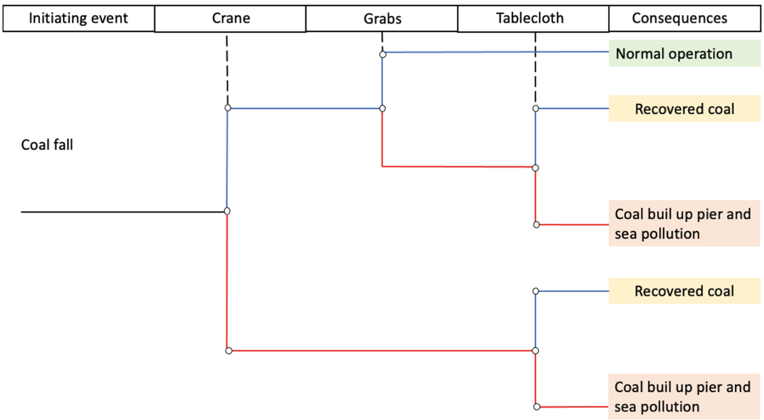


Fig. 4. Event tree used for coal discharge process.

The Bow tie is particularly useful for analysing unwanted events, as their causes and consequences remain linked together in only one framework, as showns in Fig. 5.

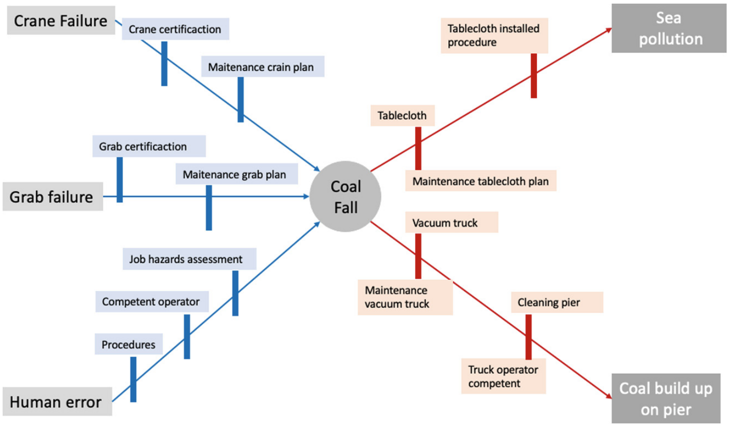


Fig. 5. Bow tie used for coal discharge process.

4 Conclusion

The use of appropriate hazard identification methods can be used to design effective procedures for safe handling of the coal discharge process. In addition, the Bow Tie analysis has shown the link between technical causes and human error. The technical causes are grab failure and crane failure. By other hand, the causes of human error in the coal discharged process can be: poor training crane operators, weak knowledge about job hazards assessment, lack of skills operators, in other words: "lack operational discipline". Finally, the consequences if not working last barriers are: coal built up on pier and sea pollution.

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Safety Concerns in a Portuguese Chemical Industry: A Workers' Perspective

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Abstract. The literature on occupational safety shows that the main safety concerns focus on physical, interpersonal and organizational aspects. Plus, there are studies that indicate experience and knowledge transmission as important aspects for the preservation of health and safety at work. A case study was conducted, in a Portuguese chemical industry, to identify workers' concerns on safety at work, and, to understand whether experience or knowledge transmission are considered in these concerns. Data was collected through the Technique of Free Association with 43 workers. A descriptive analysis and content analysis of the data were carried out. Results allow the identification of seven types of safety concerns (some are common concerns) and show that workers' experience and knowledge transmission are, in fact, considered as a concern. This underpin the originality of this study and contribute to complement occupational safety perceptions, particularly in studies in industries considered dangerous, such as chemical industry.

Keywords: Safety concerns · Workers' perspective · Chemical industry · Free association technique · Work experience · Knowledge transmission

1 Introduction

To investigate and take action in the field of safety at work implies involving workers, knowing their professional context, their activity and working conditions, and their perceptions.

If we focus on the perceptions and concerns, in particular, about safety, we know that these emerge according to the individuals, the contexts where they work, the sectors of activity [1]. The literature on this topic shows that there are several studies on workplace safety concerns carried out in different professional sectors. We highlight, for instance, studies from health, services, and industry. These studies indicate that the main safety concerns, from workers' point of view, focus on aspects such as: exposure to chemical products, musculoskeletal problems (provoked by working conditions and interactions with clients/patients), falls, burns, painful postures, the absence/lack of appropriate personal protective equipment, absence/lack of concern of managers with occupational safety issues (e.g., [2–4]). It is clear that these concerns focus on a more

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physical, interpersonal or organizational level. Some of these aspects (e.g., exposure to chemical products; risk of major environmental accidents) are particularly critical in industries where the activity involves a considerable risk for workers, but also, to a large extent, for the environment and the surrounding community (high-risk industries), such as the chemical industry [5].

To complement this reading, there are also other studies, that do not explicitly focus on the study of safety concerns, mas that point out aspects such as experience and knowledge transmission as elements to be considered in these issues of safety and health at work. For example, studies that consider knowledge transmission as a priority in occupational health and safety programs or interventions, assuming it as a way to enhance safety awareness and safety behaviors between workers, and supporting the production of materials such as safety and health guides for action (e.g., [6, 7]) or for the production of safety knowledge assuming this knowledge as mediators of safety and safety performance (e.g., [8]). With regard to experience, both the production and sharing of knowledge imply its mobilization, which contributes to the construction of security perspectives, through the knowledge acquired over time of situations and possible risks in activity [1].

Despite the fact that there are numerous works on occupational safety and the impact of the lack of safety in work and health of individuals, reference should be made to the fact that very few studies were found that address, in specific, the safety concerns that workers in high-risk industries have, and none that spontaneously mention the concerns of workers in terms of the knowledge transmission or experience, thus revealing that there is still space for reflection and empirical studies on this subject/sector.

With this background, it was conducted a case study in a Portuguese high-risk industry – a chemical industry -, in an exploratory and contextualized way, taking in consideration that the company was focused on understanding the safety of its workers, resulting from the transformations experienced over many years (e.g., aging workforce and at the same time concerns with rejuvenating the teams; technical changes in the equipment's; work accidents). Thus, our goal was to identify the concerns that workers have on safety at work and to understand whether experience and/or knowledge transmission are considered in workers' safety concerns spontaneously.

2 Method

2.1 Context and Participants

The study was conducted in a Portuguese chemical industry, more specifically in the operational areas of the company (company that produces organic and inorganic materials), within the framework of a training program aimed at exploring the issue of safety in the operational teams. The company wanted to understand the existing safety problems in their context and develop safety actions with their workers. This company, with vast years of existence, has an average age of roughly 49 years.

The participants of the study were 43 workers (of about 100 from the operational areas): 36 from the two operational factories, which assume the function of industrial chemical technicians (responsible, in rotation, for the control of the automation of the production process in the control room and the external supervision of production and quality control) or maintenance operators (responsible for the maintenance of the factories equipment's); and 7 from support areas, such as Process Engineering, Projects, Health and Safety at Work. The participants have between 23 and 65 years old and a seniority in the company and function between 1 and 45 years.

2.2 Techniques and Procedure

The data collected correspond to the spontaneous verbalizations of the participating workers, expressed through the registration of expressions or words. These data were collected within the framework of collective training sessions aimed at exploring the issue of safety at work (roughly 10 workers per session).

To collect the data, it was applied the Technique of Free Association (TFA). This is a technique, common in the field of social representations, which consists in the production of words or expressions according to an inducing stimulus [9, 10]. The TFA was chosen to allow participants to share their concerns, in an anonymous and spontaneous registration, in the form of short expressions or words, without giving any conscious guidance to their thoughts, thus allowing to collect spontaneous speech.

To apply the technique, it was presented the following stimulus to the workers: "what concerns do you have when you think about safety in this company?". Then, workers had to registered in individual and anonymous papers, words or expressions related with the stimulus.

After the registration and gathering of the data, a group reflection on the contributions was carried out in the sessions in order to enhance also the collective reflection. This was important to share different and common perceptions and to promote the debate on the issue of safety at work.

A descriptive analysis and content analysis of the data were carried out. With regard to the descriptive analysis, it was analyzed the fluidity, amplitude and richness/homogeneity of the semantic material. The fluidity allows us to know the ease with which the participants expressed themselves regarding the stimulus (expressiveness), and corresponds to the total number of words/expressions associated to the inducing question. The amplitude indicates the number of different meanings, and corresponds to the number of different significations. And, richness/homogeneity allows us to obtain information about the integration of information (greater or lesser integration) and whether the participants resort to a common dictionary (thus suggesting the sharing of one or several representations). The former, corresponds to the ratio between amplitude and fluidity, and varies between 0 and 1, whereas there is use of the same semantic universe the closer the value is to 0 (cutting point 0,5).

Regarding the content analysis, this consisted in the manual identification of categories of concerns, by exploring the main themes found in workers' registers, and the quantification of expressions/words registered by the participants.

3 Results

Based on the descriptive analysis, a total of 74 expressions/words (fluidity) and 47 different expressions/words (amplitude) were identified (each participant wrote at least 1 expression/word and 3 on average). This indicates that workers could easily express their concerns and that these have a variability associated. In relation to richness/homogeneity of data, a value of 0.6 was found, showing that workers share some common concerns and a common 'dictionary' to describe them, although there are some that are not shared by all, as we will show next, based on the content analysis.

With the content analysis, it was identified seven types of safety concerns. We present them, in a descending form, in relation to the number of expressions/words associated to the categories: 1) environmental and industrial concerns (e.g., "product leakages", "risk of exposure to chemicals", "danger/risk of explosion"; "industrial accident", "be careful with spills and leaks that occur regularly", "impact on the environment and nearby population"); 2) the lack of knowledge transmission between colleagues and awareness of workers' experience (e.g., "discussion between workers of technical problems", "workers experience", "communication/knowledge sharing", "need for more awareness on knowledge"); 3) compliance with safety standards (e.g., "use of individual protection equipment", "checking safety demands before work to be done", "need for more safety standards", "comply with company's safety standards"); 4) the conditions and organization of work (e.g., "work permits", "organization of work", "lack of monitoring in the facilities interventions"); 5) the conditions of the facilities (e.g., "aging or degradation of installations", "installations that are not prepared to work safely"); 6) health and well-being at work (e.g., "falls", "work accidents", "concern about the well-being of all"); 7) how to proceed at work (e.g., "habituation leads to carelessness", "hurry leads to accident").

The two types of safety concerns most mentioned were related with environmental and industrial issues (25 expressions/words) and the concerns related with the lack of knowledge transmission between colleagues and awareness of workers' experience (13). The less mentioned, and therefore less shared concern, was about aspects related to how to proceed at work (2). Between these two 'poles', are the issues related to the compliance with safety standards (11), the conditions and organization of work (9), the health and well-being (7) and the conditions of the facilities (7).

Has we mentioned, the richness/homogeneity of data show that there are some concerns that are shared and other that are not shared by all. The first ones, correspond to the majority of the categories, and the point of view with which they are expressed by workers is shared. Those that are not shared by all correspond, in particular, to the category "Compliance with safety concerns", where word/expressions differ in terms of content (meaning different points of view). While some workers recognize as a concern that compliance with the existing safety standards and the use of the personal protective equipment are important, others consider that there are not enough safety standards, or that the use of the personal protective equipment is sometimes a constraint to perform all tasks.

The results show that the safety concerns of the participants do not focus on one category only (e.g., physical, interpersonal or organizational), but on different dimensions related with work including knowledge transmission.

4 Discussion

The empirical data allowed us to discuss on a few topics. With this study, we realize that some of the safety concerns of the chemical industry participants reinforce the safety concerns evidence from previous studies (e.g., [2–4]), for example, health issues, working conditions, or compliance with safety standards. This indicate that there are aspects related to work, health and safety that are shared in different work/sector of activities, even if in multiple ways or with different reasons.

Some other concerns have also emerged, such as the issues of how to proceed at work (even if barely mentioned) and the issues of the importance of knowledge transmission between colleagues and the awareness of workers' experience. Regarding, in particular, this last point, the results allowed us to respond to our goal, reveling that the experience and knowledge transmission are considered as safety concerns in this particular context. Although we know that these concepts are studied and valued for the preservation of health and to take action in safety issues, pointing to the importance of participation and recognition of workers and their experience in safety processes [11–14], no references to experience or knowledge transmission as explicit safety concerns have been express in studies around this topic. In our study they were considered spontaneously by some workers, which is new data for studies on safety concerns. Besides, they were the second most mentioned concern, indicating that, although they are relatively fewer in number compared to the environmental and industrial concerns, the workers are more aware and concerned with these aspects than with other typically more recurrent issues (e.g., working conditions or health), meaning that it is, in fact, something that worries these workers, due to the fact that, in their view, it has a potential impact on their safety. I other words, we can understand that knowledge transmission and the valorization of experienced workers are important for the pursuit of work activity in safety.

The safety concerns found in this company are related with the personal experience of participants with their work activity, but also with the fact that their workplace corresponds to a company with an aging workforce and a high-risk activity that can impact the workers themselves, but also, as we perceived, the environment and the surrounding community. In a context like this one, and considering the safety concerns identified, the investment in learning, in the sharing of knowledge between workers, in the recognition and mobilization of workers' experience, and in the working conditions are, without a doubt, fundamental for the accomplishment of a work in safety.

5 Conclusion

In this study, we explore the safety concerns of workers in a Portuguese chemical industry.

We have shown that the safety concerns in this industrial company are related with work activity, health and well-being, work conditions and organization, issues beyond the physical work context (industrial and environmental concerns), highlighting, as well, concerns related with the importance of experience and transmission of knowledge.

The results obtained with this study can be the starting point for joint reflection with company leaders and the Human Resources team, in order to promote awareness about the main concerns of these workers with regard to safety issues, and to define actions that can meet these concerns. Since this study focused only on the perspective of the operational workers, perhaps it would be interesting to know, too, the safety concerns of some key players in the company (e.g., production leaders, managers, responsible for management, human resources, health and safety). Thus, as leads to future research, we suggest the development of a similar study with these interlocutors, making an intersection with the workers' perceptions.

In addition to the potentiality of results for joint reflection, the safety concerns of these chemical workers can be indicators of some aspects/concerns present in other chemical companies or perhaps in other professional contexts of the industrial sector (even though they are data from a case study, and therefore cannot be generalized), thus indicating the originality of this study, the relevance of the theme at the present time lived globally, and the contribution to complement occupational safety concerns, particularly in studies in high-risk industries.

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The Dynamic, Individual and Integrated Risk Assessment: A Multi-criteria Approach Using Big Data

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Abstract. Occupational Health and Safety Risk Assessment can undoubtedly benefit from enabling technologies of Industry 4.0, with the aim of collecting and analyzing the big data related to the occupational risk factors arising into workplaces. In this paper, the assessment of the occupational risk is addressed by means of a multi-criteria approach. Indeed, after the pre-treatment of the time series of the said risk factors by means of a segmentation algorithm, a TOPSIS approach is implemented to assess the dynamic, individual and integrated risk to which a worker is subjected over the time. Finally, a numerical example is reported to illustrate the proposed in practice.

Keywords: Occupational Health and Safety · Risk Assessment · Wireless sensor network · Multi-criteria decision making · Big data

1 Introduction

The fourth industrial revolution, often named Industry 4.0, has received a lot of attention in the industrial production context [1, 2] because it is changing organizations and processes [3] and also the human work [4]. With reference to human work, the Occupational Health and Safety (OHS) deals with the protection of workers and worksites, the reduction of occupational accidents, the minimization of insufficient informing, and the improvement of awareness of workers from a multi-disciplinary point of view [5]. In particular, the Occupational Health and Safety Risk Assessment (OHSRA) and management [6] is composed basically of these phases [7]: identification of the hazards, definition of who might be at risk, risk evaluation, precaution selection, findings record and, as last step, a process revision and eventually an update. Sgarbossa et al. [8], who focus on visions, challenges and opportunities of Industry 4.0, underlines also the need to integrate low-cost sensors, which represent big data sources, in order to set acceptable performance and risk levels for workers. Moreover, in order to improve the OHS in

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Industry 4.0, one of the main challenges of OHSRA is the dynamic evaluation of the occupational risk [9]. Collecting possible suggestions as provided in [8] and [9], this contribution focuses on the use of a wireless sensor network, i.e. a state-of-art solution to collect dynamic data from different space points, for the dynamic evaluation of the occupational risk.

Actually, the occupational risk factors arising into industrial environments are strongly heterogeneous, as well as time-dependent and space-dependent. Noise, illumination, air quality and so on vary over time and may be more or less critical depending on the positions of the worker into the operative space relative to the risk sources (e.g., machinery, handling equipment, collaborative robots and materials). Thereby, it can be stated that the occupational risk which the workers are subjected to, disregarding the specific integrated measure adopted, should be assessed both dynamically and individually. Moreover, a further consideration reinforces the need of assessing the risk individually: the overall risk which a worker is subjected to depends also on his/her characteristics (e.g., biological and anamnestic), which make each risk factor more or less critical. It is to remark that some recent papers integrate the human characteristics into mathematical planning models for production and logistics, focusing for example on learning effects [10, 11], human energy expenditure [12, 13] and aging [14]. However, as highlighted by Neumann et al. [15], there is still a scarce explicit consideration of Human Factors (HF) in Industry 4.0. Multi-Criteria Decision Making (MCDM) represents a natural candidate to achieve individual and integrated risk measures. Indeed, in recent years, MCDM has been applied to help practitioners in OHSRA [16]. The reader can refer to the reviews [16] and [17].

The first contribution referred to this research stream is [18], where a fuzzy TOPSIS is adopted for the risk assessment in a food company. More recent contributions are: [19], which adopts a FAHP to evaluate seaport security; [20], which applies a Fuzzy Decision Making Trial and Evaluation Laboratory (FDEMATEL) for OHSRA in ship recycling industry; and [21], which exploits a Fuzzy TOPSIS (FTOPSIS) for the evaluation of the port vulnerability. In our work, a TOPSIS approach is adopted for its simplicity, low computational complexity, low cognitive efforts required by decision-makers, and adequacy with treating objective criteria. However, a relevant issue arises when applying MCDM to risk assessment, which is summarized as follows. The dynamic collection of the occupational risk factors by means of a wireless sensor network leads to as many time series as the risk factors are [22].

The dynamics of these factors naturally differ from each other and depends on specific causes that may be sudden and momentary as well. For instance, the lumen value of a workbench shows a peak if a light is turned on and suddenly turned off. Furthermore, an intrinsic variance is also present into the time series of the risk factors, which is unavoidable as being the background noise of their generating processes. This represents a serious issue because a peak would distort the instant value of the risk factor and the overall stage of risk assessment, as well. In order to deal with denoised time series, a segmentation algorithm is adopted to pre-treat them, which are thus converted into polygonal paths composed by sequences of linear ramps and stationary processes [23]; this allows to represent better the dynamics of the generating processes of the occupational risk factors. Then, a MCDM approach is adopted to achieve an integrated occupational risk measure, which is also dynamic and individual for the aforementioned reasons.

The paper is structured as follow: Sect. 2 explains the adopted framework, Sect. 3 reports an illustrative example, and finally, Sect. 4 contains the conclusions and some suggestions for the further research agenda.

2 Framework

1) Risk identification: based on specific activities, products and equipment [24], we are going to list the main risks encountered. The risks identification is out of scope but in literature many methods appear to carry this task out, e.g. brainstorming, Delphi technique, checklist, expert interview, flowchart, SWOT analysis, and questionnaire [25]. This stage allows to identify the proper sensors to collect dynamic data. The output is the list of $K - risks$ to deal with.
2) Static data collection: this stage refers to the collection of static data related to the identified risks. In particular, we are interested in risk thresholds and ranges derived from regulations and further data related to workers, if necessary. For example, if the thermo-hygrometric risk is considered, the well-known Fanger's method [26] requires also the clothing insulation and the metabolic activity of workers to compute the Predicted Mean Vote (PMV). We assume that each risk is evaluated by means of one risk measure, which in turn may be computed by means of more controlled variables as in the case of the PMV. With reference to thresholds, the risks thresholds T_k and/or acceptability/ideal ranges $\left[T_k{}^-; T_k{}^+\right]$ are collected, with $k = 1, \ldots, K$. In particular, a risk may belong to:

   - $G1$ = group of risks where the risk measures have to be lower than a threshold T_k (e.g., concentration of pm10). Here the risk measure is used as it is.
   - $G2$ = group of risks where the risk measure must fall within an acceptability range $\left[T_k{}^-; T_k{}^+\right]$ centered on zero to make the risk manageable (e.g., PMV). We treat this group of risks by taking as risk measure its absolute value.
   - $G3$ = group of risks where the risk measures should ideally - in terms of comfort - fall within a range $\left[T_k{}^-; T_k{}^+\right]$ (e.g., lux). We treat this group of risks by taking as risk measure the absolute value of the difference between the risk measure and $\frac{(T_k{}^+ + T_k{}^-)}{2}$. Any other risk may be brought back to one of the aforementioned groups.

3) Dynamic data collection: real time data collection for the risks identified (stage 1). According with the group to which each risk belongs (e.g., $G1$, $G2$ and $G3$), we collect different risk measures by using the risks thresholds T_k and/or acceptability/ideal ranges $\left[T_k{}^-; T_k{}^+\right]$. It is also observed that aligning the sampling rates of different sensors can be a difficult task. However, thanks to the next segmentation stage, we do not need to perform the alignment because the segmentation converts single points into polygonal paths. Hence, different sampling rates are traced back to a unique rate, named time bucket, that can be fixed arbitrarily (see stage 4).

4) The segmentation used to eliminate background noise and outliers, and also to avoid different sampling rates into the sensor network. In particular, we adopt a piecewise linear segmentation by using the "segmented" package in R [27, 28] with "selgmented" function, which selects the number of breakpoints of the segmented linear relationship according to the Bayesian Information Criterion (BIC). This allows to compare models with more than 2 breakpoints till the maximum number of breakpoints indicated [27]. The outcome of this segmentation consists of a series of linear models, separated by breakpoints, that fit the sub-processes of the risk measures composing the overall process. We suppose to discretize a single time period (e.g., day) into T time buckets, with $t = 1, \ldots, \mathrm{T}$ (e.g., hours). The assumption for simplicity is that there is only one space point to control and only one time period to be taken into account, the output are the risk measures for every time bucket, that is S_{kt} with $k = 1, \ldots, K$ and $t = 1, \ldots, \mathrm{T}$. Obviously if more periods are taken into account the data collected became rapidly big data. The subsequent TOPSIS approach adopts the said S_{kt} values as the risk measures (i.e., the values of criteria) of the time buckets (i.e., the alternatives) of the time period to which they belong.
5) TOPSIS application by using the time-varying S_{kt} to derive a dynamic, integrated, and individual measure of risk. The inputs are segmented the risk measures S_{kt} for every time bucket in the controlled space point (stage 4).

The goal is to achieve the global ranking of the time buckets according to the descending order of their overall risks. Hence, the Ideal and Anti-Ideal solutions are the most and the least critical time buckets in terms of the overall risk, respectively. Moreover, without loss of generality, we suppose that all S_{kt} refer to beneficial criteria. The steps are the following ones:

i) Risk prioritization (i.e., weighting of criteria). In order to make the risk assessment customized to individual needs, we can adopt several approaches to assign the weights w_k to criteria (e.g., [16, 29]), either objective or subjective. The weights are such that:

$$\sum\nolimits_{k=1}^{K} w_k = 1 \tag{1}$$

ii) Normalization of the risk measures S_{kt}:

$$n_{kt} = \frac{S_{kt}}{\sqrt{\sum\nolimits_{t=1}^{T} S_{kt}^2}}\ \forall k = 1, \ldots, K\ \forall\, t = 1, \ldots, \mathrm{T} \tag{2}$$

iii) Computation of the weighted risk measures:

$$c_{kt} = w_k * n_{kt}\ \forall\, k = 1, \ldots, K\ \forall t = 1, \ldots, \mathrm{T} \tag{3}$$

iv) Computation of the Ideal and the Anti-Ideal Solutions, which are indicated respectively with $\boldsymbol{A}^{+} = \left(A^{+}{}_{1}, \ldots, A^{+}{}_{K}\right)$ and $\boldsymbol{A}^{-} = \left(A^{-}{}_{1}, \ldots, A^{-}{}_{K}\right)$, as follows:

$$A_k^{+} = \max_{t=1,\ldots,T} \{c_{kt}\}\ \forall k = 1, \ldots, K \tag{4}$$

$$A_k^- = \min_{t=1,\ldots,T} \{c_{kt}\} \ \forall k = 1, \ldots, K \tag{5}$$

v Computation of the relative distances of time buckets as:

$$r_t = \frac{d_t^-}{d_t^+ + d_t^-} \ \forall t = 1, \ldots, \mathrm{T} \tag{6}$$

Where d_t^- and d_t^+ represent the Euclidean distances of time bucket t to $\boldsymbol{A}^-$ and $\boldsymbol{A}^+$, respectively.

The r_t value represents the individual and integrated risk measure of time bucket t, and thus the risk assessment results dynamic implicitly. Since TOPSIS is not affected by rank reversal, we add to the set of time buckets also a fictitious alternative with all the risk measures fixed at their thresholds, which is named integrated risk threshold. This allows to understand how the integrated risk measures are approaching over the time to the border scenario.

3 Numerical Application

We apply our proposal within an administrative office during an entire working day (8h) by considering a single workstation. The identified risks are: exposure to pm10 and pm2.5, thermo-hygrometric and illumination (i.e., $K = 4$). A low-cost integrated sensor is used to collect dynamically all the data (i.e., controlled variables) required to compute the K risk measures, which are supposed of equal importance (i.e., $w_k = 0.25$ with $k = 1, \ldots, 4$). Expect for the thermo-hygrometric risk, where the controlled variables are used to calculate the PMV as the thermo-hygrometric risk measure according with the Fanger's method [26, 30], the other controlled variables are used directly. Table 1 reports the controlled variables.

Table 1. Controlled variables.

Risk	Controlled variables	Unit of measure	Resolution	Range
pm10 exposure	pm10 concentration	$\mu g/m^3$	1 $\mu g/m^3$	[0;1000]
pm2.5 exposure	pm2.5 concentration	$\mu g/m^3$	1 $\mu g/m^3$	[0;1000]
Illumination	Ambient light	Lux	0.1 lx	[0;120000]
Thermo-hygrometric	Temperature	$°C$	0.1 $°C$	[-40;85]
	Relative Humidity	RH	0.1 RH	[0;100]

For the PMV, we use the Metabolic Rate (met) of a sedentary activity and the clothing insulation (clo) for indoor winter clothing by using the reference values reported in UNI-EN-ISO 77:30:2005 [30] (see Table 2).

Table 2. Parameters values for the PMV calculation

Parameters	Standard values	Values	Unit of measure
Air temperature	-	Dynamically collected	°C
Mean radiant temperature	25	-	°C
Air velocity	0.1	-	m/s
Relative humidity	-	Dynamically collected	%
Clothing insulation level	-	1	clo
Metabolic rate	-	1.2	met
External work	0	-	met
Basal metabolic rate	58.2	-	w/m^2

Table 3. Reference thresholds for the risks and relative regulations

Risk measure	Regulation	Type of environment	Thresholds	Unit of measure
pm10	ISTISAN report (ISS) [31]	Indoor	<90 (8 h)	[μg/m^3]
pm2.5	ISTISAN report (ISS) [31]	Indoor	<40 (8 h)	[μg/m^3]
PMV	UNI EN ISO 7730 [30]	Indoor	$> -2, < +2$	[-]
Light	UNI EN 12464 [32]	Operational offices	>250, <350	[lux]

For the risk thresholds we use the values reported in Table 3, where the respective regulations are listed as well.

Looking at the thresholds in Table 3, it is noted that pm10 and pm2.5 can be treated as risks belonging to $G1$, PMV to $G2$ and light to $G3$. Figure 2 reports both the real and the segmented (red dashed lines) time series of pm2.5/pm10 concentrations and ambient light. Figure 1 reports both the real and the segmented (red dashed lines) time series of temperature and relative humidity, which lead in turn to the time series of PMV. The segmentation is always performed using a maximum number of breakpoints fixed at 10. It can be noted that the segmentations of pm2.5 and pm10 allow to eliminate sudden drops and peaks probably due to the instability of the sensor, whereas the segmentation of the light behaves differently due to its intrinsic erratic-ness. Conversely, the segmentation of temperature and humidity follows the time series as closely.

Figure 1 shows the dynamics of the integrated risk measure r_t (Eq. 6), which settles on values far from the integrated risk threshold (blue dashed line). It is worth to observe that the light suddenly increases r_t in the time slot 02:00 pm-03:00 pm, but without getting it close to the integrated risk threshold. The other measures influence less r_t due to their lower variability. Moreover, they are always very far from their thresholds.

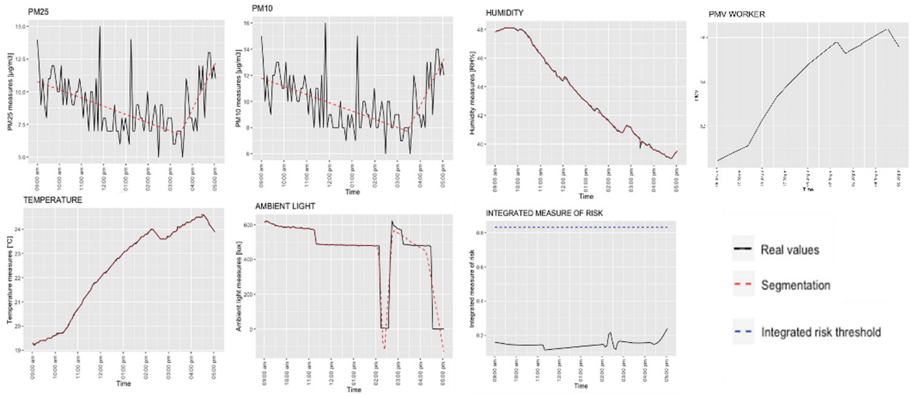

Fig. 1. Time series segmentation and the integrated measure of risk

Indeed, pm2.5 lies into the range [5; 12.5], which is very far from 40 and the same holds for pm10, while the PMV is always acceptable as lies into the range [0; 0.7].

4 Conclusions and Further Research Agenda

In order to bridge the gap reported in literature [8, 9] and to put at the service of occupational health and safety the Industry 4.0 technologies, we proposed a framework to asses a dynamic, individual and integrated risk measures by means of a TOPSIS approach. The numerical application allows to highlight the benefits of our proposal not only in research but also in practice. Future research will be devoted to the indirect elicitation of the weights to be assigned to the various risk factors as well as to supervised approaches of machine learning to predict automatically the said risk measures. Moreover, after having assessed the overall risk, several preventive approaches for the risk control may be proposed and then applied to industrial settings.

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Safety and Human Factors

Adopting the CRIOP Framework as an Interdisciplinary Risk Analysis Method in the Design of Remote Control Centre for Maritime Autonomous Systems

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Abstract. Humans are increasingly asked to interact with automation in complex and large-scale systems. The International Maritime Organization (IMO) has started working on regulations for Maritime Autonomous Surface Ships (MASS). For the foreseeable future, unmanned ships will most likely be under supervision from a Remote Control Centre (RCC), called constrained autonomy. We see a need to include the end-user and carry out a risk-based design analysis, considering the operational quality of the RCC. This paper proposes an approach based on the CRIOP method, short for Crisis Intervention and Operability analysis. Could this framework be adapted to the evaluation of RCC used for MASS operations? What critical scenarios should be used for evaluations of the design/HMI of an RCC? The paper recommends Operational Envelopes to describe the constraints of the system and concludes with recommendations regarding an interdisciplinary, collaborative, and anticipatory analysis of the HMI to enhance operator performance and reliability.

Keywords: HAI · HMI · Remote control centre · Maritime autonomous systems · Risk analysis · ConOps · Use case · CRIOP · Scenario analysis

1 Introduction

On the topic of MASS, the majority of papers published to date focuses on technical aspects of the ship operations and design, indicating that most scholars focus on the high-end components of the system, while organizational and human-oriented issues remain under-explored [1]. Without changes in the regulatory framework, safe interactions between conventional ships and MASS will be a significant challenge. In the foreseeable future, it is doubtful that MASS can operate without human supervision and intervention [2]. Thus, a technology-centred approach will miss the critical human element in MASS operations. Focus on controls, software, and sensors will inevitably

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be of limited use if little attention is afforded to the human operators' needs in the larger system [3]. This article presents a method to facilitate risk analyses to ensure a safe and resilient design of an RCC and the human-automation interface (HAI).

2 Background

MASS could better be an abbreviation for Maritime Autonomous Ship *System*, as they are complex socio-technical systems consisting of equipment, machines, tools, technology, and a work organization. The system includes functions on the ship as well as onshore – not the least the RCC. Designing such a system should follow principals of socio-technical design, like involving the future users of the new systems. Some of the leading methods for assessing safety in complex systems (e.g. STAMP, FRAM), take the necessary systemic perspective that explores the relationships between causal factors within the systems and addresses the complexity known to be important for improving safety in modern organizations [4]. However, for novel systems like MASS, the knowledge level on detailed designs is low, and the uncertainty still high.

Consequently, it is not easy to apply such systemic safety models to support the initial design phase as they rely on detailed and high-qualitative data. Besides, the methods share a challenge of being time-consuming, resource-intensive and needing extensive expert knowledge to facilitate the analysis. In this early phase, we need a more straightforward cross-disciplinary method, including the end-user, to carry out a risk-based design analysis.

3 Risk-Based Design

According to current best practice, MASS will have to be approved according to principals for "Alternatives and Equivalents" [5], which is fundamentally a risk-based approach. In national guidelines, this is partly translated to a strong focus on the ship's intended operation that needs to be described in detail [6]. This description is part of the Concept of Operations (CONOPS) that most class societies and the Norwegian Maritime Authorities requires. Risk-based design (also known as Design for Safety) is a formalized methodology, introduced in the maritime industry as a design paradigm to help bestow safety as a design objective and not a constraint. In short, it means carrying out risk analysis and consider potential risk in the different phases of design and hence treat safety as a life cycle issue. The goal is to use the information obtained from the analysis to engineer or design out accidents before they occur. A risk-based approach is recommended by Lloyd's Register [7] and DNV [8]. Structured risk-analyses should be performed on several abstraction-levels, typically utilizing several different risk-analyzing methodologies [8]. One method is the CRIOP method, which can describe and model risk qualitatively and use best practices to ensure that human factors issues are integrated into the design.

4 CRIOP – Crisis Intervention and Operability Analysis

CRIOP is an established, standardized scenario method for Crisis Intervention and Operability analysis. The methodology was developed primarily for the oil and gas industry, back in 1990 [9]. The initial scope was a scenario-and-general-checklist method for evaluating offshore control centres (CC) focusing on the human aspects in terms of conditions for successful crisis handling. Since then, the methodology has developed through collaborations between regulatory authorities, operators, research institutions, contractors and consultants, to include/consider HMIs, best practices standards and Human Factors. Integrated operations and e-Operations are now included as remote support, or remote operations are more common, due to organizational and technical changes. Today, CRIOP is used to verify and validate an RCC's ability to handle all operational modes safely and efficiently, i.e. normal operations, maintenance, disturbance/deviations, safety-critical situations.

The key elements of CRIOP are checklists covering relevant areas in the design of a control centre, Scenario Analysis of critical scenarios and a learning arena where the operators, designers and managers can meet and evaluate the optimal control centre [9].

The CRIOP process consists of four major work tasks:

1. **Prepare and organize** by defining, gather necessary documentation, establish an analysis group, identifying relevant questions and scenarios and set a schedule.
2. **General Analysis (GA)** with checklists to verify that the CC satisfies the stated requirements based on best industry practice (a standard design review).
3. **Scenario Analysis** of critical scenarios. An experienced team of end-users should perform the analysis to validate that the control centre satisfies the actual needs.
4. **Implementation and follow up:** At the end of task 2. and 3. the findings and recommendations are documented, and an action plan is established.

The method can be applied at different phases of the lifecycle, as shown in Fig. 1 below.

This paper focuses on the methodology's applicability in the early phase, the Conceptual Design phase. Here, concepts, automation level, HMI/Alarms (displays, controls, and communication interfaces), and necessary layouts should be developed. Results from preliminary task analysis, function allocation and job design analysis should be available before starting a CRIOP. However, RCC for MASS does not yet exist. Hence, such analyses are difficult to conduct due to the lack of established domains or users. Based on methods presented in [10], a pilot domain must be created. With a layout of a pilot domain for an RCC with operational envelopes in place, the CRIOP process can start.

We ask if the CRIOP framework could be adapted to the evaluation of RCC used for MASS operations. The general checklists must be updated, but the core ergonomics and risk-influencing factors (alarm philosophy, physical work environment, training) will be similar for an RCC for MASS and an offshore installation. Nevertheless, the risk analysis of a MASS and an offshore installation is quite different. We ask what key scenarios should be used for evaluations of the design/HMI of an RCC. Hence, we focus on the applicability of the work task 3 in the framework, the Scenario Analysis.

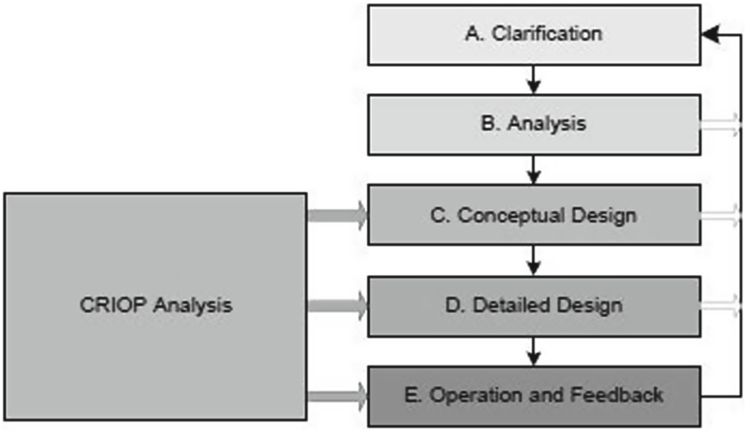

Fig. 1. Integration of CRIOP analysis in ISO 11064 design process (adapted from [9]).

5 Operational Envelope and Use Cases

The AUTOSHIP project has published an architectural concept [11], where the MASS' intended operations are broken down into smaller sets of generalized tasks, i.e. use cases. Each use case will be defined by operational constraints, e.g. geographic complexity, traffic complexity, worst-case weather, visibility conditions, etc. Together, these use cases define the MASS' Operational Envelope. This concept was first proposed in [13], calling it the operational design domain (ODD). The name was later changed to Operational Envelope to distinguish it from the ODD often used in the context of autonomous cars.

Each use case in the operational envelope describes and define both the automation's and the human's responsibilities, and the conditions that determine when responsibilities changes. [14] introduce two other important concepts, the maximum response time T_{MR}, and the response deadline T_{DL}. T_{MR} is the maximum time interval a human operator need from an alert is raised to he/she is at the control position and has gained sufficient situational awareness to take safe action. T_{DL} is defined as the minimum interval until a situation arises that the automation cannot handle. [12] introduced the idea of Constrained autonomy, which is now formally defined as a property of a sub-space of the operational envelope where the automation system at all times can calculate T_{DL}. By issuing an alert to the operator when $T_{DL} \leq T_{MR}$, one can assure that the operator will intervene in time when the automation can no longer handle a situation. The operational envelope also includes descriptions of what happens when the envelope is exceeded. The MASS must then fall back to a state that poses the least risk to life, environment, and property, so-called "Minimum Risk Condition" (MRC).

6 Remote Control Centre

As MASS are novel systems, one of the main challenges is that we have no experience from the operation or design of an RCC for MASS yet. We must base our experience from other domains such as aviation, automated road transport, or centralization of ship control done on the bridge. However, some basic principles are known:

i. Most of the time, ship operations are relatively easy to automate, e.g. transit in fair weather and non-complex traffic situations. These operations should be automated, and it is not necessary or desirable to have an operator in or on the control loop. It will be too boring for a human.
ii. More complex situations will typically develop slowly and can be identified early by the automation system, e.g. worsening weather or increasing traffic (T_{DL} is known and relatively long - on the order of half an hour).
iii. Even in a more complex situation, it should be possible to automate operations, e.g. sailing in more congested waters. Automation should, in most cases be able to handle encounters between one other ship and the MASS. However, the situation becomes more ambiguous with two or more other ships (T_{DL} is known but is shorter – on the order of minutes). The safe state could be to halt ships or reduce speed to mace the situation controllable – thus, controllability is a crucial issue.
iv. A primary driving factor for MASS is to operate many smaller ships rather than one large. Having smaller vessels increases the frequency of service, which is necessary to, e.g. transfer cargo from road to sea [12]. With crew onboard, this will not be economically feasible. There will be more than one ship to monitor from the RCC.

Based on these principals, the RCC operators will typically be in charge of several ships and not closely monitor only one ship. They will be alerted to situations that the automation cannot handle and will need to take the right action. Different types of ships and shipping operations may require other RCC configurations.

7 Review of the CRIOP Scenario Analysis

The Scenario Analysis is designed to verify that the CRO (Control Room Operator) can perform the task while considering cognitive abilities, human-system interaction and other performance shaping factors. The analysis is human-centred, focusing on the CRO's interaction with the system, including communication with other personnel. Emphasis is on how the systems support the operator's situation awareness and decision making in different situations.

The Scenario Analysis assesses the RCC's actions in response to possible scenarios. Based on the scenarios, a dynamic assessment is made of interaction between essential factors in the control room, e.g. presentation of information and time available. The methodology suggests using Sequentially Timed Events Plotting (STEP) diagrams for a graphic presentation of the scenario events. For each event, questions related to the SMoC (Simple Model of Cognition) should be asked. A checklist of performance shaping factors should also be used to ask additional questions to elaborate on answers received.

The Scenario Analysis follows four main activities:

1. Selection of a realistic scenario
2. Description of the scenario employing a STEP diagram

3. Identification of critical decisions
4. Analysis of the decisions and possible evaluation of barriers

7.1 Selection of Realistic Hypothetical Scenarios

CRIOP recommend adapting scenarios based on incidents that have occurred and hypothetical incidents constructed by the analysis group. For MASS, when the operations are described in the operational envelope, the use cases will directly define scenarios. The challenge is to select the most critical ones and investigate if the use cases do not cover other critical scenarios in the operational envelope. One source for critical scenarios can come from hazard identification methods (e.g. HazId, HazOps, FMECA). It should consider both hazards like malfunctions of the system and hazards outside the control structure. A preliminary hazard analysis (PHA) is typically established in the general analysis of a concept design. Here, participants from different fields of expertise come together in brainstorming sessions to identify hazards and rank their impact. In the AutoFerry project, such analysis used a simple checklist-based approach and identified the most critical hazardous events to be related to the control system, communication between software and hardware components, the interaction between the ferry and recreational users of the channel and hacking and cyber-sabotage[15]. Wrobel made an assessment based on 100 ship accidents and suggested three prominent cases to be explored, i.e. groundings, collisions and fires [16].

MUNIN was the first project to develop a technical concept of a MASS back in 2015. Since then, several published papers discuss potential risks of MASS operations [17–19] contributing to a database of hazards and critical scenarios.

In reviews of risk analysis methods for MASS, the STAMP method [20] with STPA is recommended as it defines safety as a control problem, making it desirable for complex systems. The analysis identifies unsafe control actions and unsafe transition control actions that will lead to a hazard in a particular context and worst-case environment. These unsafe actions could also provide valuable input for scenarios.

7.1.1 Criteria for Selecting Scenarios

The CRIOP analysis should consider a few relevant scenarios, identified as key scenarios. In [9], the criteria for selecting these scenarios are listed. Adapted for MASS, the overall criteria should be operator involvement, hazard potential, complexity (to make sure the operators stress with peak workload) and acceptance (scenario accepted as possible by all participants).

An essential feature of MASS is the dynamic levels of autonomy that may change during a voyage depending on certain conditions. Hence the following types of human-automation interaction cases must be considered for Scenario Analysis:

1. Handover from automation to the operator. For both long and short T_{DL}.
2. Operator handling parts of the operational envelope that automation cannot handle.
3. Operator actions in the case of a fallback situation to MRC.

7.2 The STEP-Model

STEP is relatively simple to understand and provides a clear picture of the course of the events to illustrate what can happen in a scenario. The graphic presentation is helpful for common ground to discuss possible hazardous events. A timeline on the horizontal axis keeps the events in order, and the connected "actors" are listed in a column. The relationship between events, what caused each of them is shown by drawing arrows to illustrate the causal links.

7.3 Identifying Critical Decisions

The analysis can start when the scenarios are documented. For each event involving an operator, questions are asked to identify how the systems support the operator's situation awareness and his/her ability to make decisions and execute actions. The CRIOP Handbook provides checklists with questions related to the scenarios and performance shaping factors depending on if the event relates to the operator receiving information (human-system interface) or making decisions (training, procedures and time available). The checklist helps identify potential error sources in the information systems, the operator's ability to achieve an adequate level of situation awareness, and whether sufficient information is available to allow the CRO to make decisions when required. Identified problems are called "weak points". Using the identified weak points, the Scenario Analysis's final step is to identify measures that should be taken to improve the identified weak points. Prior experiences suggest that CRIOP helps identify significant challenges between human operators and automation, as the best practice guidelines are used. Often mentioned issues are the ability to grasp the situation "at a glance", and simplifying automation steps such that the operator understands the action taken by the automation.

8 Summary

This paper presents an approach based on the CRIOP method. The framework can be adapted to the evaluation of RCC used for MASS operations. Experiences from implementing automation in other domains have found a strong need to base the development of best practices from Human Factors when there is a need for human control. CRIOP could be a risk analysis tool as we ask what can go wrong, why and how, and discuss different hazards and risks. Even though CRIOP is not based on probabilistic quantification, the participants' opinion on the scenarios is vital, contributing to a qualitative evaluation of risks. Critical scenarios for evaluations of the design/HMI should involve handover situations and fallback situations where the human operator is expected to intervene.

9 Need for Further Research

The next step is to test the feasibility of using an adapted version of CRIOP for hazard identification and assessment of a conceptual design of a real RCC. A case study with participants to validate the method focusing on the RCC and the HAI in a situation where the human is alerted to take control, is the HAI sufficiently well designed to satisfy T_{DL}? Furthermore, in the situations where the human operator has the responsibility for overall operations, will he/she be able to do this job at a satisfactory safety level?

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Producing Human Factor Recommendations in the Aviation Sector

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Abstract. This paper explores how Human Factors (HF) recommendations for the design of systems, the design of equipment and the design of operations are produced in the Aviation Sector. It also investigates to what extent they rely on the use of HF methods available in the literature. The paper builds on semi-directive interviews from HF experts and practitioners in several Aviation Organizations in Europe and beyond. The interviews captured real HF intervention practices that are described based on actual design examples. The paper presents an overview of practices used amongst the Aviation Industry to generate HF design recommendations within different organizations collaborating on a common European Project. It discusses how HF experts and practitioners produce efficient HF recommendations, and what is needed not only in terms of methods to carry out these recommendations but also and possibly more importantly that which is required from a broader organizational perspective.

Keywords: Human Factors (HF) · Human Factor (HF) Recommendations · Aviation · Human Factors Methods · Risk management

1 Introduction

Human Factors (HF) are an essential component in the Safety Management and Risk Management process in all High-Risk Industries and have been recognized as critical in Aviation Safety and effectiveness [1, 2]. The concept of HF arose in aviation in the 40s at the end of WWII [3] and was officially used in 1957 to represent the application of scientific knowledge, facts, models and theories derived from various disciplines of human science [4] including industrial engineering, psychology, physiology, medicine, sociology, management science, business and anthropometrics [4, 5]. HF consider the capabilities, abilities, limitations and other characteristics of human behavior to propose suggestions or adaptations to the design of tools, equipment, machines, systems, jobs, tasks, and procedures to maximize safety, productivity, and comfortability [3, 6]. As a result, HF are a pinnacle in aviation and aim to apply knowledge regarding human behavior in the design of systems [1, 7], in training, in policies or procedures to enhance human performance through the design by implementing and disseminating HF; particularly as long-term improvements in aviation will primarily be the result of HF solutions [1, 2].

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Significant advances in Human Factors (HF) research during the past decades have led to the development or improvement of several HF methods that aim to facilitate the integration of HF proactively and reactively. They are meant to not only identify and analyze HF contribution to (un)safety but also propose HF recommendations that enhance safety through error reduction and mitigation. Over the past few decades, academics have proposed numerous methods, concepts, tools and theories to better capture Human Factors in Safety. According to Carayon [5], there are key elements required by HF experts to adequately apply HF recommendations. Specifically, HF experts ought to: (*i*) be perceived as credible and flexible with a strong capacity for learning and listening; (*ii*) command strong interpersonal skills that facilitate communication; (*iii*) be knowledgeable in HF and possess the skills to implement the recommendation. Similarly, numerous international regulatory bodies [8, 9] have developed requirements and guidelines regarding HF. A repertoire of Safety Methods including HF methods have been characterized in NLR's [10] Safety Methods Data Base. Based on the assumption that HF methods can be useful to different organizations, the SAFEMODE European project aims at characterizing the latest standard HF methods according to academic partners or method developers to support organizations in their integration of HF in design. This leads us to ponder: To what extent are the repertoire HF methods used in practice?

The paper investigates to what extent these methods are used in-practice within the Aviation Sector to generate HF design and operations recommendations. More generally, it explores how HF recommendations for the design of systems, the design of equipment and the design of operations are produced in the Aviation Sector. The paper builds on semi-directive interviews from a variety of HF experts and practitioners in several Aviation Organizations in Europe and beyond, to investigate the real practices used within each organization to integrate HF into the design. The interviews detail not only real HF intervention practices within each organization and their production conditions, but they also explore the organization's use of HF methods available within the literature. More generally, the paper presents an overview of practices used within the Aviation Industry to generate HF design recommendations within different organizations collaborating on a common European Project (see acknowledgement section). It also discusses how HF experts and practitioners produce efficient HF recommendations and what is required to produce them. This paper reaches beyond the work by Carayon [5] as it identifies organizational culture elements required to produce and integrate efficient HF recommendations not only in terms of methods but also from a broader organizational perspective.

2 Method

This paper relies on a qualitative research strategy and builds on qualitative semi-directive interviews from seven HF experts and practitioners in several Aviation Organizations in Europe and beyond. Numerous participants (ten) consisting of Human Factor Specialists, Researchers and Professors with HF training from Aviation, Rail and Academia from the SAFEMODE project were interviewed remotely due to the COVID-19 pandemic. However, for the purpose of this paper, the authors focused on the seven interviews from three organizations within the Aviation Sector consisting of two Airline Manufacturers and an Air Navigation Service Provider (ANSP). It is important to note that the organizations interviewed are not representative of the whole spectrum of Aviation Organizations given that these are large organizations that develop large systems or operations and hence all contain simulators and internal HF expert means. In-depth interviews [11] were conducted with two to three HF experts and practitioners from each of the three organizations. Considering the limited number of interviews, the data consisting of interviews and organizational documents were processed manually by thematic analysis [12, 13]. This led to the identification of not only HF practices but also the conditions, especially organizational, to efficiently integrate HF into the design. Each of the interviews was transcribed and validated by the interviewees as research for Good Practices in HF (Table 1).

Table 1. Study participants from Aviation Organizations that have contributed to this paper (the Interviews were conducted within the framework of the SAFEMODE project)

Organization		Date	hh:mm	Code	Role	Interview Code
Org. 1	Manufacturer	2019-02-17	02:30	P01	HF Specialist	O1P01
Org. 2	ANSP	2019-02-26	01:00	P02	HF Specialist	O2P02
Org. 2	ANSP	2019-02-26	01:00	P03	HF Specialist	O2PO3
Org. 3	Manufacturer	2019-03-03	00:30	P04	HF Specialist	O3P04
Org. 3	Manufacturer	2019-03-03	00:30	P05	HF Specialist	O3P05
Org. 3	Manufacturer	2019-03-03	00:30	P06	HF Specialist	O3P06
Org. 1	Manufacturer	2019-03-10	01:30	P07	HF Specialist	O1P07

3 Results

The results section is presented in two subsections. The first subsection commences with a description of the HF methods and processes employed in practice, within the organizations interviewed, to efficiently integrate HF into the design (Sect. 3.1). Moreover, the interviews demonstrate that integrating HF into design reaches beyond the sole HF methods paradox, as it further necessitates several organizational conditions that are detailed in the second Subsect. 3.2.

3.1 To What Extent HF Methods Are Used in Practice

HF recommendations for the design of systems, the design of equipment and the design of operations are produced in the Aviation Sector.

The findings show that the use of standardized HF methods is limited in these Aviation Organizations. These findings are not surprising given that HF methods, like any other "tool", are elements that to be useful must be designed both with the end-user in mind and by knowing the context of use [14]. As a result, HF methods need to be suited to the context of use. From the interviews, all three Aviation Organizations studied rely upon the use of simulators, combined observations, debriefings or interviews, brainstorming sessions, and thus at this level of non-detail or of abstraction, there cannot be a universal method. However, such HF approach is only applicable when the Organization has access to simulation devices.

We argue that HF methods are customized to the individual organizations and their characteristics and hence it is not possible for a complete HF method to be universal. However, most HF methods contain embedder human factors knowledge, which may be transferable from one organization to another or even from one sector to another. The outcome of the interviews challenges the initial assumption that HF methods are relevant in their general state to other High-risk industries, as they may not even be applicable to other organizations within the same industry, given they are so widespread that their efficiency is limited.

All three organizations describe "User-Centered Design Processes" that share numerous commonalities. However, at a lower level of detail, each organization develops an organization-specific HF method or HF process involving HF methods that rely on existing material (experience and knowledge base) and rather than merely on these generic methods. As a result, HF processes and methods of each organization are context-specific and are dependent on the available resources (technical including simulators, human including HF experts, organizational including managerial support).

As previously stated, all three organizations rely on the use of simulators. As a result, this availability of a design process simulation devices introduces yet another source of adaption within the HF process. As mentioned by one interviewee:

> *"[This] is consistent with our resources, as we have simulators very early in the design phase, so it is possible to make assessments and therefore design modifications upstream. When you only have a simulator one year before the end of development, if there is an expensive recommendation to modify a system, it will not take place because it is too expensive unless the modification impacts the safety of the system 'one way or another'. Aircraft manufacturers cannot all have the same means and we do not all have the same cooperation strategies with suppliers" (O1P01)*

Prior to embarking on a simulation, all three organizations identify a priori potential HF concerns. Once again, none of the organizations rely on a standard HF method as such; instead combining HF knowledge available in the literature which they adapt to aviation, with experience and expert knowledge. Specifically:

> *"The HF process is based on an assemblage of knowledge on human functioning a priori and the production of knowledge through interviews with operational staff or even by setting up experiments in simulators (…) For each function, we followed an analytical approach that included a large matrix of HF criteria (from the literature, the most usable, and from aeronautic experience) which makes it possible to ask questions" (O1P01)*

"We interviewed the affected ATM actors about their concerns and the potential benefits of the concept" (O2P02)

"We check issues experienced by other manufacturer's planes and determine if those situations could occur with our products" (O3P05)

Next, the organizations rely on an iterative process involving simulations, tests, debriefing sessions and/or interviews with the 'operators' involved as well as with potential future users.

"*Each year, we also organized a global evaluation, integrating all the functions, to evaluate with test and airline pilots, the usability of the cockpit as a whole" (O1P01)*

"So, we were present during the simulation sessions and the discussions, made observations, went directly to ATCOs if we had a question, analyzed the results of the questionnaires (which was put together by the project team)" (O2P02)

"We use system tests in flight during the development phase to also perform the HF evaluations including subjective methods to ask the pilot to perform the flight using the system and to respond regarding the quality of the system... we evaluate the new system using a group of pilots and after the flight, we process their opinions" (O3P06)

Without elaborating as to the details of their individual HF process and methods, each of the sizeable organizations interviewed favor in-house HF methods. The interviews illustrate this is due to the need for HF interventions that fit to the global organizational setting including the existing processes, the available resources, and the contextual factors. These in-house methods are also adapted to the development of specific products and operations. Therefore, what can be expected from generic HF methods? A source of HF-related knowledge-based rather than a ready-to-use operational approach. Some generic HF methods do embed interesting generic HF knowledge. However, whether this generic knowledge is applicable and relevant in all organizations, and how it is to be utilized requires further reflection and possible adaptation.

Furthermore, the interviews also demonstrated that producing HF design recommendations entails much more than HF methods. It also necessitates certain organizational conditions to enable possible and efficient HF interventions that are thus also required to integrate HF into the design.

3.2 The Organizational Conditions Needed to Efficiently Integrate HF into Design

According to the interviewees, integrating HF into the design of systems or operations also relies on a number of organizational conditions at different levels. At a global level, it requires the recognition of HF inputs within the organizational culture. At the design processes level, it requires the involvement of HF experts from the onset and throughout the design phases. At the design project level, it requires a modus operandi whereby HF experts, as well as all the other participants, constructively work together.

I. **HF knowledge and input are recognized as valuable in the organizational culture**
Recognizing the value of HF insight entails dedicating resources to HF and granting HF experts with a voice that is carefully considered. Such actions must reach beyond the formal integration of HF and HF experts into the organization's written processes.

"We have a good approach to HF at [organization 1]. And it has to do with more and more recognition and acknowledgement of the role of HF in the design [...]. On paper we have a clear implementation of when HF need to intervene, the scope of HF, but in real life, there are situations where the HF participation is delayed or is not at the level we would like it to be for lack of time, resources, people, and consideration of the main HF contributions. There is an issue in the education of the organization of the importance of HF despite that the HF is written and documented" (O1P07)

"One or two HF experts worked on each of the 15 new functions of the [Aircraft] - at the time we had a team of about fifteen FH experts" (O1P01)

"include[s] HF experts or people with knowledge of HF from the conception to assess the implications of having the human performance characteristics that you want to have within the system" (O3P04)

"There is also the element of respect and acceptance of the importance of HF specialists, and that the suggestions made by HF specialists can bring added value. The same weight needs to be given to suggestions that arise from a safety perspective and a HF perspective" (O2P02)

II. **Involving HF experts in the design from the onset**
Providing HF experts with resources is not sufficient to integrate HF into the design. It also requires involving HF experts in design project teams not only from the onset, thus positioning HF experts to deliver early and hence feasible and affordable recommendations, but also at all stages of the design.

"There is a principle that says: "involve users in all stages of the design and development facilitated by systems engineering, HF experts, and safety expertise". I fully support this statement" (O2P02)

"The ideal HF should be considered in the entire project, from the conception through to development and certification and during product operations. [...] This ensures that the information is generated at the time when it is needed and that we can capture the important issues, therefore avoiding the need for rework and ensuring we produce better products" (O3P05)

"Since we captured [the issue] during the development stage of the design, we were able to modify it ... and did not have to wait for the next version" (O3P06)

III. **All the actors work synergistically as a global team**
In order to make a significant difference in a design project, HF experts need to be fully integrated into the project team. In practice, they need to participate in all the discussions and exchanges held in relation to the design, providing HF input

that is considered and deliberated with the remainder of the team. This allows for the rationality and the outcomes of the design to be co-developed within the team, ensuring that all aspects (objectives and constraints) be considered, thereby generating global added-value for the design.

"The value of having a very good team with safety experts, ATM experts, and the technical team (e.g. system engineers, designers) means that everyone brings to the table their knowledge in their particular fields" (O2P02)

"An HF intervention […] is not an isolated action to improve the operations or the system. It rather facilitates the continuous involvement of the air traffic controllers (our end-users), the ATM experts, the technical experts, safety specialists, human factors analysts and the project manager. At the end of the validations, we jointly come up with recommendations and requirements – the key to success is basically the team effort, clear communication and continuous involvement" (O2P02)

"The team effort and involvement should be there from the beginning, so this does not mean that the experts need to be involved at some time in the project. Everyone from the beginning needs to share their assumptions" (O2P03)

"My team […] produces systems design recommendations from an HF perspective, [by working and] interact[ing]with other specialists such as engineers and so we do not produce recommendations on our own" (O1P07)

4 Discussion and Conclusion

This study aims to identify what HF methods are implemented in practice, within three Aviation Organizations, that integrate HF into the design.

The findings identify three conditions required to integrate HF interventions within the Aviation Industry and include: an organizational culture recognizing HF knowledge and inputs; the involvement of HF experts in design projects from the onset; and the synergistic effort of all actors as a global team.

Several limitations requiring further avenues of research were identified in this study. Possible biases may be induced from the limited number of organizations (3), the limited number of interviewees from each of those organizations (2–3) and the lack of range of size of the organizations selected (all large) which are not representative of the Aviation Industry.

Despite these limitations, this research sheds light on the HF methods paradox, whereby HF methods are not the sole aspect to be examined to effectively integrate HF into the design of systems and/or operations.

Although one could imagine that HF methods may compensate to an extent for the lack of internal HF expertise, our research confirmed Carayon's [5, p. 663] results that "*HF experts should be perceived as credible*". Furthermore, HF recommendations need to be not only relevant from an HF perspective, but also considered within the design. Producing relevant HF studies and analyses, as identified by Carayon [5, p. 663] requires "*strong interpersonal skills,[…] a strong capacity for learning and listening, and [to be] flexible […in order to] facilitate communication between the HF experts, on one* *hand, and the adopters and end-users on the other hand*". Our research demonstrates an additional critical element for HF considerations to be considered in the design. Specifically, the integration of HF experts as full members of the design team, contributing to the discussions and debates surrounding design options, thus considering all the dimensions of the design project. This role involves not only interpersonal skills to interact with other design team members but also organizational conditions and culture to co-construct recommendations that are acceptable by all design stakeholders. Efficient HF recommendations are not produced independently or autonomously and then 'exported' into the design team. Instead, they are suggested, discussed and debated among the design team connecting all the perspectives.

Another potential counterproductive effect of considering the integration of HF into design through the sole angle of HF methods arises as HF recommendations that are produced at an advanced stage of design may no longer be economically or technically feasible to accommodate. This may reinforce the initial belief that HF recommendations are not efficient. This may also lead to design options that transfer the burden to training to compensate for the lack of HF considerations at the design stage. In order to develop a solid rationale in favor of an organizational culture recognizing the value of HF, it would be interesting to evaluate the impact of the early and full vs the late and superficial integration of HF in the design on the training needs and global efficiency.

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Character Accentuation as a Psychological Risks Criterion of Fly-in-Fly-Out Personnel in the Far North

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Abstract. Due to the fact that during long-term work on a fly-in-fly-out method in the Arctic, destructive changes in the specialist's personality and activities can develop, it is necessary to take into account not only the adverse qualities formed at the hiring time, but also their occurrence and development likelihood, i.e. study the psychological risks. The most unfavorable changes in the workers' personality are professional destruction (changes in the existing structure of activity and personality that adversely affect labor productivity and interaction with other participants in this process), which include character accentuations. As the research result, it was established that the character accentuation is more pronounced than among the southern regions representatives. The workers in diamond mining are characterized by hypertensive and cyclothymic combined with exaltation. The oil specialists are characterized by hypertensive, pedantic and cyclothymic. The fly-in-fly-out workers in the south are most markedly demonstrative and pedantic.

Keywords: Psychological risk · Fly-in-fly-out work · Character accentuation · Functional status

1 Introduction

The fly-in-fly-out labor method is used in many countries of the world: Russia, Australia, Norway, the USA, Great Britain, Canada and others, both on land and in the sea in oil and gas production on offshore platforms. The fly-in-fly-out labor method in the Far North and the Arctic is actively used at the present time, which is associated not only with the developed territories expansion, but also with the emergence of new industries types, which include the large facilities construction. However, these regions belong to the extreme zone and are located in unfavorable conditions for the specialists' work and life [4, 9, 14]. Studies [2, 4, 13, 14] show the unfavorable climatic conditions influence, industrial and social factors on the physical and mental health state, as well as the fly-in-fly-out workers' psychological status. One of the key problems is sleep disturbance in fly-in-fly-out workers [3, 8, 10, 12]. The studies emphasize that fly-in-fly-out work has many physiological, psychological and social consequences that lead to the normal sleep-wake cycle disruption. Due to the fact that during long-term work on a in fly-in-fly-out

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method in the Arctic, destructive changes in the specialists' personality and activities can develop, it is necessary to take into account not only the unfavorable qualities formed at the hiring time, but also their occurrence and development likelihood, i.e. psychological risks study. Psychological risks are the professional personal destructions occurrence likelihood and the workers' unfavorable functional states formation during the labor functions performance due to the long-term impact of negative social and domestic and production factors with insufficient personal and environmental resources [5].

The most unfavorable changes in the employee's personality are professional destruction - changes in the existing activity and personality structure, which negatively affect labor productivity and interaction with other participants in this process, which include character accentuations [5].

Character accentuations are excessively enhanced and pronounced individual character traits or their combination, manifested in a person's selective attitude to psychological influences of a certain kind, making the person vulnerable to the traumatic environment influences with good or even increased resistance to other reality aspects [7]. Revealing the severity level and character accentuations type of fly-in-fly-out workers in the Arctic as a criterion for psychological risks will make it possible to develop optimal measures for their management.

This study purpose is to identify and describe the character accentuation features as a psychological risks in the professional activities criterion of fly-in-fly-out personnel in various industries in the Far North.

2 Materials and Methods

To achieve this goal, a study was carried out through three expedition trips to the oil production, the diamond production and the object "Crimean Bridge" construction. 227 fly-in-fly-out workers (aged 21 to 63) took part in the study.

The research methods are studying documentation, monitoring the work process, questionnaire survey, psychological testing, using the methodology "Character Accentuation" by G. Shmishek, K. Leonhard [7].

Due to the fact that another psychological risks in professional activity criterion is unfavorable functional states, we assessed their levels among fly-in-fly-out workers using instrumental psychophysiological methods:

1. Complex visual-motor reaction (CVMR), performed by means of the psychophysiological testing device UPFT-1/30 "Psychophysiologist", which allows to assess the mental and operational performance level, as well as the functional status level.
2. Variational cardiointervalometry (VCM), performed by means of the psychophysiological testing device UPFT-1/30 "Psychophysiologist". This is an functional status assessment and cardiovascular system adaptive capabilities using the variational cardiointervalometry method. These indicators are a vulnerable link in the adaptation to the Far North and the Arctic conditions with polar stress syndrome.

Statistical analysis methods are descriptive statistics, multidimensional variance analysis, two-stage cluster analysis, conjugacy tables using the χ^2-Pearson criteria.

3 Results

3.1 Prevailing Character Accentuations Types as a Psychological Risks in the Professional Activities Criterion of Fly-in-Fly-Out Personnel in Various Industries

Multivariate tests (Pillai's trace is 1.090 at $p = 0.001$) show statistically significant the production type influence on the character accentuations severity of fly-in-fly-out workers. Statistically significant influences are also confirmed by the results of evaluating the intergroup factors effects, where for all character accentuations types p-significance level is 0.001.

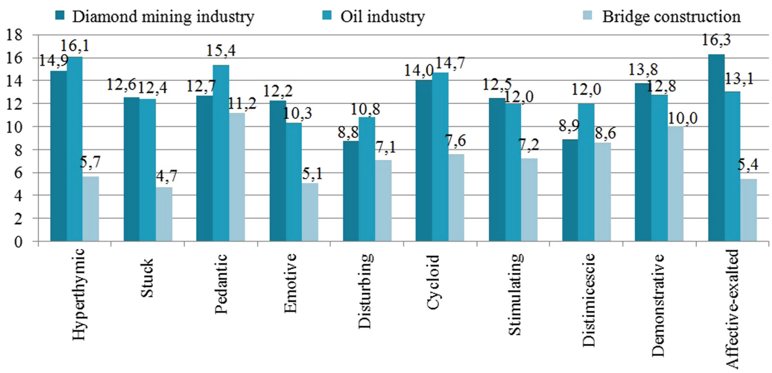

Fig. 1. Character accentuations of fly-in-fly-out personnel in various production types

Figure 1 shows that among fly-in-fly-out workers in the Far North, character accentuations are more pronounced than among workers in the southern fly-in-fly-out, that will help to preserve themselves during their extreme activities.

The fly-in-fly-out oil production personnel combines such features as hyperthymic, pedantic and cycloid character accentuations types. Such workers can be characterized as self-critical, responsible and executive; they follow the rules. At the same time, these workers are indecisive, cautious and pessimistic. They are characterized by insecurity and powerlessness in external factors front. The need to make decisions in the face of an information lack and time limits; situations requiring the efforts mobilization, endurance cause unfavorable conditions in these workers.

This is also confirmed by our earlier studies, which, on the basis of the revealed the workers' character accentuations combination features, identified two clusters: with an exalted demonstrative stuck character accentuations style and with pronounced anxious-cyclothymic character accentuations [6].

Diamond mining workers are characterized by hyperthymic and cycloid, combined with exalted, which can ensure high activity in finding solutions to problems and performing professional tasks. They are characterized by high efficiency, persistence in achieving goals and the ability to defend their point of view. They are also arrogant, power-hungry, prone to unjustified risks. Prolonged repetitive work can be difficult for these workers. The work results depend on the change in mood. They can be quick-tempered and irritable.

Unfavorable conditions in these workers can be caused by uncertainty situations, strictly regulated professional activity conditions, monotonous work, as well as their merits underestimation.

For workers on the south, the most characteristic are demonstrative and pedantic, which mutually exclude each other's manifestations. But dysthymic, which is also more pronounced, indicates a lack of energy and activity, a tendency to reflect. At the same time, these employees may be characterized by conscientiousness, thoughtfulness, and seriousness.

3.2 The Interaction of the Prevailing Character Accentuations and Functional State of Fly-in-Fly-Out Personnel in Various Industries

In order to determine the differences in personal characteristics among various industries workers with different functional states, a multivariate analysis of variance was carried out, where the industries (oil and gas, diamond mining, bridge construction) and the functional state (favorable and unfavorable) were correlated with the personality accentuations types diagnosed using the G. Shmishek's and K. Leonhard's research methodology personality accentuations.

Multivariate tests (Pillai's trace is 0.241 at $p = 0.015$) show statistically significant influences of the industries type and functional state on the character accentuations severity. According to the intergroup factors effects assessment, there are statistically significant differences in various industries fly-in-fly-out personnel with different functional states for the following character accentuations types: disturbing ($p = 0.028$) and dysthymic ($p = 0.049$). For other character accentuations types, no statistically significant differences were found.

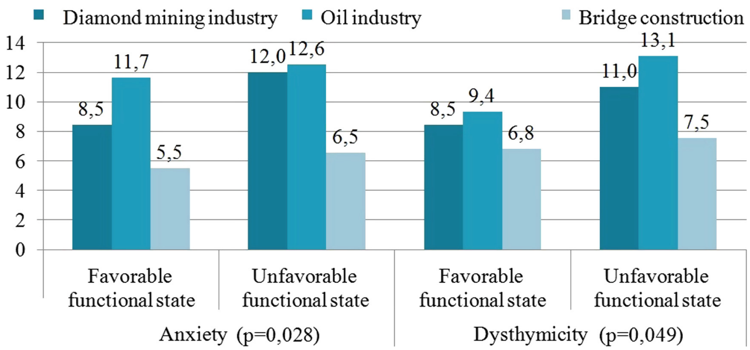

Fig. 2. The fly-in-fly-out personnel' character accentuations in various production types

Figure 2 shows that the anxiety level is higher among fly-in-fly-out personnel of all industries types with an unfavorable functional state. We can say that anxiety has a disorganizing effect on professional activity, which is manifested in the workers' functional state, especially in conditions where the requirements for adaptation exceed their reserves.

We can also say that the anxiety level among fly-in-fly-out personnel in the North is higher than among workers in the south, which may be due to the production specifics and their extreme professional activities.

If we compare the anxiety indicator among workers in the diamond mining and oil and gas production industries in the Far North, we see that oil and gas production specialists are more anxious. Perhaps they develop a responsibility sense in connection with the stressful or emergency situations occurrence that require quick response and resolution.

Figure 2 also shows that the dysthymicity level is higher in all industries types fly-in-fly-out personnel with an unfavorable functional state. It manifests itself in the suppression of mood, slowness, volitional efforts weakness. Dysthymicity among fly-in-fly-out personnel in the Far North is also more pronounced than among fly-in-fly-out workers in the south, and is most pronounced among specialists in oil and gas production.

4 Discussion

In the article, we analyzed character accentuations as a criterion for fly-in-fly-out personnel' psychological risks in various industries. E.F. Zeer says that one of the conditions for the professionally determined accentuations formation is adaptation to a new professional activity [17]. With successful adaptation, there is a tendency to compensate for accentuations, and professional maladjustment significantly increases the their severity level and leads to professional personality destructions. E.F. Zeer, in his professional destruction concept, says that professionally determined accentuations begin to develop from this professional development stage and can be compensated for with successful adaptation to activities. Therefore, it is important to assess their severity among fly-in-fly-out personnel in order to develop targeted adaptation programs for new employees.

Our study results are consistent with the A.G. Ananenkov's and co-authors results, who revealed the accentuated personalities growth with an increase in the length of stay in the North [1]. In this regard, it is necessary to carry out preventive and corrective measures that contribute to development of the fly-in-fly-out workers' personal resource.

In other authors studies, the employees' character accentuations were not directly studied, but at the same time, other personal characteristics were revealed that can be attributed to the fly-in-fly-out personnel's psychological risks in the professional activities criteria. In the oil and gas research review, K. Parks suggested that compared to onshore fly-in-fly-out workers, offshore workers experience increased anxiety levels, more sleep problems and greater stress [9].

The Roozbehani's, Tarkhan's, Alipour's et al. study results showed that long-term employment on offshore platforms is associated with personality changes. Workers with a fly-in-fly-out work experience of 4 years or more on an offshore platform compared with employees with less than one year work experience had higher neuroticism rates and lower rates of extraversion, compliance and consciousness [11].

Australian studies also found significantly higher depression and anxiety rates among fly-in-fly-out workers than among the general population [15], the anxiety and stress risks are twice higher for young workers (18–33 years) than for older workers [16].

In our previous study, devoted to the character accentuations study as a psychological risks criterion for the main gas pipelines builders in the fly-in-fly-out work organization in the Far North, the following was established. The main gas pipelines builders with less than five years fly-in-fly-out work experience have expressed alarming, exalted and cyclothymic accentuations. The main gas pipelines builders with more than five years fly-in-fly-out work experience are characterized by following character accentuations: stuck, hyperthymic, anxiety and emotive.

Regarding the relationship between two psychological risks in professional activity criteria - character accentuations and functional state, it should be Y. Korneeva's and N. Simonova's noted study, which was carried out at an oil and gas industry in the Arctic. It was found that attribution to a favorable or unfavorable functional state is associated with the demonstrative workers's character accentuation type severity. The oil and gas production enterprise fly-in-fly-out specialists in the Arctic with a moderately pronounced demonstrative character accentuation type have favorable functional states during the fly-in period. Therefore, the pronounced demonstrative accentuation type presence indicates a high psychological risk, which can lead to a decrease in the activities effectiveness. The oil and gas producing enterprises employees characterized by a different character accentuations combination will have different psychological risks, and, therefore, different approaches to their psychological support are required. The oil and gas production company fly-in-fly-out employees in the Arctic are classified into two clusters depending on the character accentuations types severity combination: exalted demonstratively stuck and anxiously cyclothymic [6].

5 Findings

Character accentuations as a psychological risks in professional activity criterion among fly-in-fly-out workers in the Far North are more pronounced than among the southern fly-in-fly-out representatives, which can contribute to a better adaptation process. Diamond workers are characterized by hyperthymic and cycloid, combined with exalted. The oil industry specialists are characterized by hyperthymic, pedantic and cycloid. The fly-in-fly-out workers in the south are most pronounced demonstrative and pedantry.

If we talk about the interrelation of two psychological risk in professional activity criteria - functional states and character accentuations, then statistically significant differences were revealed only in the anxious and dysthymic character accentuations types severity in various industries fly-in-fly-out workers with their favorable state varying degrees. These traits are most pronounced in workers with an unfavorable functional state, which indicates their disorganizing influence.

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Lean Ergonomic Impacts on Manufacturing Systems

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Abstract. Ergonomics and Lean Production have similar goals. Ergonomic issues should be deemed waste by Lean Practitioners because of the effect on the health, safety, and productivity of employees in the manufacturing process. The transition from a place to another place, for example, creates physical and mental fatigue and increases wasted time, which is one of the most common wastes in production processes. The paper presents the question: What is the analysis format that can be conducted by incorporating vision among Lean Manufacturing and Ergonomics? What are the benefits of this integration? This paper presents a case study that illustrates the use of an integrated approach, developed by the design science research method, in a production process. To complement is presented a theoretical and practical framework, integrating Ergonomics and Lean Manufacturing to produce a technical report of ergonomic analysis of the task. This study was carried out at a Brazilian refrigeration compressor manufacturer located in the São Paulo State countryside in different manufacturing processes.

Keywords: Ergonomics · Wastes from work processes · Lean manufacturing · Lean ergonomics · Ergonomic analysis

1 Introduction

Ergonomics and Lean Production have similar goals. Ergonomic issues should be deemed waste by Lean Practitioners because of the effect on the health, safety, and productivity of employees in the manufacturing process [1]. The transition from a place to another place, for example, creates physical and mental fatigue and increases wasted time, which is one of the most common wastes in production processes [2].

What is the analysis format that can be conducted by incorporating vision among Lean Manufacturing and Ergonomics? What are the benefits of this integration? This paper presents a case study that illustrates the use of an integrated approach, developed by the design science research method, in a production process. To complement is presented a theoretical and practical framework, integrating Ergonomics and Lean Manufacturing to produce a technical report of ergonomic analysis of the task.

The study was carried out at a Brazilian refrigeration compressor manufacturer located in the São Paulo State countryside in different manufacturing processes. Using

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a risk assessment and labor analysis instruments, as MTM - System Time Measurement [3], we determined and suggest new methods for labor situations. To reduce or eliminate waste movement, we used ergonomics improvement proposals (physical and mental), workplace assessment, task execution time, and the physical environment, aspects of physical ergonomics (layout, tools, equipment).

In order to identify the issues, waste, unnecessary and overextended movements, the performed tasks were analyzed with the interactive package of the Golden Zone method [3], biomechanical assessment [5], and the MTM [3].

After introducing the changes, itis safe to assume that the risks have been minimized. We achieve more significant benefits to the well-being, safety, productivity, and comfort of workers [6] when the environment is adjusted to human factors.

2 Methodology

Given the objective of carrying out an ergonomic analysis of a workstation, with emphasis on physical ergonomics and the application of the MTM and Golden Zone method, this work was developed in a manufacturer of compressor assemblies for refrigeration, which is continuously involved in process improvement, concerned both with productivity and the health of its employees.

For this study, the Golden Zone tool, the biomechanical analysis of work activities, and the MTM-UAS Method were used through videos filed in a company database.

The study took place in the electrical sector, in the assembly line of metallic connection boxes, in the terminal block capacitor's assembly post, electrical harness, and fixing cables.

As inclusion criteria for selecting the position, the first bottleneck of the line (31.9 s.) with the potential to optimize the process, improve the flow of the line and reduce muscle fatigue from the implementation of ergonomic improvements was verified. A second applied criterion was the integration of the biomechanical analysis of the activity and MTM in the assembly post of the terminal block capacitor, electrical harness, reconciling the problems of biomechanical overload of upper limbs and spine, the layout of the post, number of movements, and execution time of the activities.

Physical ergonomics were considered, from the prescribed task description, assessment of the workstation, the time of execution of the activity, and the physical environment (layout, tools, equipment). The activities performed were analyzed with the Golden Zone tool's integrated application.

MTM is a predetermined time system that provides tabulated times for the human body's movements to estimate the duration of task execution and can be used to determine the method and the time that a qualified operator needs to perform an activity with specific performance.

The MTM analysis becomes a precious source for ergonomic analysis. With the simplification of very complex movements and the reduction of useless movements, improved productivity and ergonomics are obtained. The UAS module of the MTM system is designed for series production, and for this reason, it was used in this study. Initially, the parts, components, and tools used in carrying out the task were identified, the distance ranges, and the descriptions of the activities via the system, then, the sequence of movements of the task was broken down into 18 operational steps.

To collect data related to body segments during the task development, we applied the Sue Rodgers checklist [7] to quantify and identify the biomechanical risk factors.

3 Results and Discussion

After applying ergonomic analysis, emphasizing physical ergonomics, the MTM-UAS and Golden Zone method, to detect activities that can be optimized and thus eliminate waste with movement, the result enabled the production's optimization process and the reduction of muscle fatigue.

From the ergonomic analysis of the activities, it was possible to identify the following residues related to the analysis of the activity: Lack of method in carrying out the activity, and there are different sequences of processes to assemble the components in the connection box; Large movement distances, parts/components, outside the ideal working area (Golden Zone).

The results of the MTM method identified waste in process time due to the pieces being positioned in the distance range 2 ($>$20 to $\leq$ 50cm) and 3 ($>$50 to $\leq$ 80cm). The picking distances of the pieces (terminal block and electrical harness) were not positioned at the ideal range, requiring movements with a more significant extension than necessary, generating waste of movement, time, and muscle fatigue. With the application of the MTM-UAS method, it was possible to identify the clear potential for improvements related to the movement of picking up the piece.

Through biomechanical analysis of the activity, it was possible to diagnose that the activity required inadequate spine movements (twisting and inclination of the trunk) since the terminal block capacitors (2nd whip) was outside the Golden Zone. The Suzanne Rodgers checklist was applied to obtain a more accurate analysis of biomechanics. The activity presents a moderate risk (yellow) for the left shoulder and vertebral column after application.

Three proposals for ergonomic improvements were made in order to improve the work area and reduce/eliminate unnecessary movements and fatigue, such as repositioning the harness box on a support above the line in front of the employee, repositioning the packaging of a terminal block capacitor closer to the line and an adjustment without layout, bringing the workstations closer together, decreasing as well as the picking distances of the pieces, eliminating the anti-ergonomic movements of the left shoulder and spine, optimizing the processing times and handling waste.

After implementing the improvements, the Sue Rodgers tool and biomechanical analysis were applied again, where it was possible to conclude that the risks to the left shoulder and spine were minimized.

After readjusting the layout, repositioning the packages closest to the employee, the reach distance went from range 3 ($>$50 to $\leq$ 80cm) to range 1 of the MTM ($\leq$20cm), reducing the handle distance on average by 45cm. Regarding the activity's execution times, there was an 11% optimization in the processing time, going from 30.77 s to 27.4 s, and a 13% gain in productivity.

4 Conclusion

Given this work's objective, applying the described tools, we conclude that the Lean Manufacturing system's application provides an expressive reduction of waste, leaner, and optimized processes. In Lean environments, the intensification of the requirements and content of tasks and the optimization of processes can compromise employee health and safety. For this reason, Ergonomics has a good interaction between work and its performers in its field of action, providing that all work must be carried out in comfort and safety, preserving employees' physical, social and psychological integrity.

The application of Ergonomics and the MTM-UAS method improved the activity's performance, eliminating unnecessary movements, optimizing the process, and minimizing ergonomic risks and muscle fatigue. The significant gain with implementing the improvements in the layout was the improvement of productivity and reduced waste and improvement in the working conditions, reducing the biomechanical overload, making the processes more straightforward, more reliable, and lean. There is no effective production if employees are fatigued or sick, proving that an efficient lean process is one that considers human factors in its value chain.

It was evident that the application of Lean Manufacturing, Ergonomics, and MTM brings enormous benefits to employees' productivity and health. Focusing their efforts on continuous improvement with the elimination of waste, since it is possible to obtain improvements in regarding the method and time of execution of the task, taking into account human factors, which in addition to the efficiency of the production system, prioritize the health and safety of the employee.

Ergonomics is necessary for all Toyota System methodologies. It will undoubtedly bring essential improvements to the workers' health and comfort in their processes, suggesting new studies applying standardized work to assess the biomechanical demand, productivity, and comfort at work.

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Safety, Prevention Management and Training

The Safety Measure Effectiveness Assessment Tool (EAT)

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Abstract. Measuring the effectiveness of measures implemented to improve safety is multi-dimensional. The method "Safety Measure Effectiveness Assessment Tool" (EAT) described in this paper provides guidelines to assess measures. It distinguishes six levels of measure assessment: (i) the measure itself, (ii) the implementation of the measure, (iii) knowledge, skills and attitudes related to the measure, (iv) actual behavior in daily work, (v) conditions promoting or hindering transfer into daily work, and finally (vi) the measure's effectiveness regarding safety. Applying the EAT requires three steps: (i) indicator definition, (ii) descriptive measurement and, (iii) normative assessment.

Keywords: Safety · Safety management system · Human factors · Effectiveness assessment

1 Purpose of the EAT

This paper describes the method "Safety Measure Effectiveness Assessment Tool" (EAT) in summary. A detailed specification of the EAT is published in [1].

Safety Management Systems (SMS) aim at identifying and mitigating risks [2] or at enhancing resilience [3] in order to improve safety. To do so, often safety measures (e.g. optimized standard operation procedures) are implemented. If corresponding measures refer to human factors (HF-measures), normally a change in human behavior is aimed at (e.g. a consequent double-checking). Whether or not the intended effect of a HF-measure really is achieved needs to be monitored by the SMS. However, since human behavior is influenced by numerous factors, checking whether a measure achieves its objectives is challenging. Evaluations may refer to different aspects, such as the implementation of the measure, its impact of the measure, and/or its effectiveness. Focusing on the implementation only is not sufficient as even a successful implementation does not mean that this measure actually is effective as intended. If a measure for example encompasses a prescribed number of lessons in form of classroom instruction for all employees, the assessment of the implementation may consist of taking records whether or not everyone attended the lessons. Of course, a measurement like this is not at all valid for assessing whether the measure achieves the intended effect, i.e. improving safety. Moreover, if indicators are selected in an inadequate way, "managing the measure" may

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sneak in [4]. An example for this is, when backlog in maintenance is selected as a safety performance indicator: Reducing maintenance quality may optimize the backlog without improving safety. Accordingly, focusing on implementation rather than on effectiveness may provoke that the pure implementation of a measure becomes an end in itself and the actual objective of the measures vanishes.

Against this background we developed the EAT, that conceptualizes six assessment levels. On each level the EAT provides guidelines regarding (a) the identification of relevant indicators, (b) the operationalization and (c) the assessment of these indicators. A detailed description of the EAT can be found in [1].

2 Levels of the EAT

Following, the six EAT-levels of measure assessment are described (cf. [1] for details).

Level 1 The HF-Measure. HF-measures build the starting point for effectiveness assessment. HF-measures are designed to achieve specific objectives related to safety, e.g. less occurrences, incidents or accidents when using a specific tool.

Level 2 Implementation. On this level an implementation check examines whether measures were in fact implemented. This is done by verifying the means taken to implement the measures. For example, it can be checked whether posters were distributed in hallways, whether manuals were rewritten, whether workflows and responsibilities were redefined or whether configurations for machines were adjusted. It can also be counted how many participants attended the trainings. Usually, the implementation is easy to measure since most of the implemented means are visible. However, the implementation does not yet make sure that the measure delivers its intended outcome even though it is a necessary precondition.

Level 3 Knowledge, Skills and Attitudes. HF-measures normally require a change in human behavior. Preconditions for behaving in accordance with the HF-measures are corresponding knowledge, skills and attitudes. Knowledge means being aware of the measures as well as their rationales and their directives for behavior. Knowledge can be taught. Skills, which can be trained, refer to the concrete ability to behave as required by the measures. Attitudes towards the measures incorporates whether one agrees with the measures or not. This is assumed to have a strong motivational influence on humans' behavior according to measures. Attitude requires persuasion.

Level 4 Behavior. Behavior is what humans do in a particular situation. Measures related to human factors usually require a change in human behavior, which is assumed to outperform current behavior. Knowledge, skills and attitudes are preconditions for behavior.

Level 5 Transfer Promoters and Barriers. In addition to humans' knowledge, skills and attitudes, transfer promoters and barriers are decisive factors for behavior. These are work conditions determining whether the behavior required by HF-measures can be applied in daily work. While transfer promoters facilitate a certain behavior, transfer barriers hinder it.

Level 6 Outcome. The outcome of HF-measures corresponds ideally with the pursued objective of the measures. The outcome is only an indication of the effectiveness of measures, since causality is difficult to prove due to the influence of many factors, including luck and coincidence.

3 Steps of the EAT-Application

Applying the EAT requires three steps: (i) indicator development, (ii) descriptive measurement of indicators, and (iii) normative assessment of indicators. Indicators can refer to all levels of measurement as described above. Thereby distinguishing between the descriptive measurement aiming at an objective description of the subject matter on the one hand and a normative assessment aiming at a judgment on the other hand is core of the method. In such a way cognitive biases when applying the EAT should be reduced. Below, the three steps are described (cf. [1] for details).

3.1 Step 1: Indicator Development

The EAT application starts with the measure to be assessed. As measures normally are not directly measurable or appraisable, indicators need to be identified. A simple example for a measure, which will be used to illustrate the following steps, is "decisions need to be double-checked".

Step 1.1: Definition of Indicator. Indicators operationalize constructs, i.e. make them measurable and appraisable. Indicators may be of quantitative (e.g. number of participants in double-check training) or of qualitative type (e.g. behavioral markers when double-checking in daily work). For both types of indicators, characteristic features need to be described (e.g. different ways of double-checking). Indicators can refer to each of the six levels of measure assessment as described above. With reference to "decisions need to be double-checked", examples of questions are listed in the following, for which indicators need to be defined.

Level 1 The HF-Measure. Is the measure actually specified? Is defined, what the measure encompasses? Is clear, what a decision is and what double-checking looks like?

Level 2 Implementation. Is "double-checking" included in standard operation procedures? Are training sessions organized? Do people attend training sessions?

Level 3 Knowledge, Skills and Attitudes. Do employees know the double-checking and its rationales? Do employees know corresponding directives? Do employees have the ability to double-check? What are the employees' subjective attitudes regarding the double-checking and the corresponding behavior?

Level 4 Behavior. What different ways of performing double-checks can be distinguished?

Level 5 Transfer Promoters and Barriers. Does the double-checking fit into existing processes? Are there any existing procedures that are contradictory to double-checking? Are the resources (personnel, time and material) needed for double-checking available? Are supervisors committed to double-checking? Do supervisors provide support for double-checking? Do peers commit to double-checking?

Level 6 Outcome. How can it be recognized whether the pursued objective of the HF-measure is achieved?

Step 1.2 Definition of References. While indicators are required for descriptive purpose, references are needed for normative appraisal. Consequently, references specify for each indicator, acceptable and non-acceptable values. However, the corresponding scale may have more levels (e.g. very poor, poor, acceptable, good, very good ways of double-checking).

3.2 Step 2: Descriptive Measurement of Indicators

Indicator measurement as well as indicator appraisal are data-based. Hence, in step 2 methods for data collection as well as for data evaluation need to be defined. The EAT describes different methods for data collection (e.g. questionnaire surveys, interviews and observations) as well as for data evaluation (e.g. statistics, qualitative content analysis) and refers to corresponding standard quality criteria such as objectivity, reliability, and validity.

3.3 Step 3: Normative Assessment of Indicators

Finally, step 3 of the EAT is the normative appraisal of the measure. For this purpose, the actual state described in step 2 is interpreted using the reference defined in step 1.2. This allows diagnosis such as “The average duration of the double-checks indicates that the double-checks are performed thoroughly in daily work” or “78% of the double-checks are performed as required by the measure. This value is 2% below the objective of at least 80% of the double-checks performed completely thoroughly”.

4 Conclusion

The EAT has been developed in close cooperation of researchers with industrial partners. It aims at supporting safety management by defining and applying measurements to systematically assess the effectiveness of HF-measures. It thereby explicitly distinguishes six levels of measure assessment to make sure, that actually effectiveness is assessed and not implementation only. The EAT-guidelines described in [1] are completed by indications regarding implementation of the EAT into existing safety management processes as well as regarding training needs for EAT users.

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Compliance You Said? Why May Safety Critical Operators Deviate from Procedures? A Military Aviation Perspective Comparing Operators from Different Operational Fields

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Abstract. From aviation accident and incident investigation reports, procedural deviations can be considered as recurring causes related to Human Factors. This research aimed at identifying perceptions of military aviation safety critical personnel regarding deviations; and their motivations to deviate. Deviations were suspected to be frequent but rarely reported or discovered. The choice was thus made to call upon sharp-end operators' experience using a self-completion questionnaire to gather quantitative and qualitative data from Aircrew, Air Traffic Management, and Maintainers. The results suggested that the procedures themselves, resources, mission, organizational culture, and organizational environment can be considered as motivations to deviate. The organizational culture was potentially found as predominating over the considered group's professional culture, and deployed operations as catalyzing deviations. A negative label was generally attributed to deviations by respondents. However, they reported that creative problem-solving in acute situations may require to adapt the existing decisional algorithms to reality of complex systems.

Keywords: Human factors · Safety management · Military aviation · Procedural deviations · Organizational Culture

1 Introduction

Context related, and organizational factors can drive or lead safety critical operators towards certain decisions in order to get the work done. These decisions could result in

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actions at the edge of compliance or clearly deviate from prescribed procedures, potentially causing unwanted consequences or preventing unwanted effects from occurring [1]. The challenge for complex and dynamic work settings and roles is providing rules that standardize task behavior that however also allow to deal with contingencies. This vision on procedural deviations is in line with the two models proposed by Dekker [2] and later reviewed by Hale and Borys [3]. Model 1 sees procedures as the expression of the one best way to perform tasks, including all possible circumstances. Procedures are designed by experts and aim at protecting against errors and mistakes of operators. In this model operators are considered limited in their knowledge and background compared with the experts. Model 2 considers procedures as supporting and guiding knowledgeable operators. Procedures are resources for further adaptation, and not requiring blind compliance; not replacing competence and professional judgement [3]. While Dekker [2] considers the models as exclusive, Hale and Borys [3] reconcile and combine both models.

The present study was performed in a European military aviation organization. The potential military aviation specifics are not explicitly considered in the academic literature. Research on military organization might either not have been performed or not published, and the motivations for procedural deviations in such an organizational context are not known hence the reasons. When facing incidents and accidents the organization's safety department notices that deviation from procedures is one of the causes leading to the occurrence. In most of the cases, the investigation output concerning procedural deviations is limited to what did happen (identifying the procedural deviation) and the 'why' is seldom deeply addressed. This is the direct consequence of the resources' allocation for incident investigations and the traditional approach to incident/ accident investigation focusing on Safety I [4] or Model 1 [2]. The issued recommendations are mostly of the classical 'brief'/'re-brief' type or lead to an additional rule or procedure addressing the specific case. Air Traffic Management (ATM) investigation on the other hand does often lead to a revision of the involved procedure. Identifying and understanding potentially specific reasons why safety critical personnel from the organization deviates from procedures would facilitate more suitable remedial and prevention actions possible.

Hudson et.al. [5] suggested four main reasons for violations, i.e., expectation, powerfulness, opportunities and inadequate work planning. Expectation refers to the individual's estimation of the likelihood to deviate. Powerfulness deals with the feeling of superiority, competence and skill based on experience. Opportunities are defined as the possibilities an of an individual to perform better and more efficient along with their subjective evaluation of the improvement. Furthermore, Mc Donald et al. [6] considered that the professional culture influences deviating behavior to compensate for the deficiencies of the organizational system.

Woods et al. [7] proposed categories of cognitive system factors and considered that the operator cognition is the source of operator actions. The suggested categories are knowledge factors, attentional dynamics and goal conflicts. Hollnagel [4] proposed the Efficiency-Thoroughness-Trade-Off (ETTO) where depending on the situation thoroughness is substituted with efficiency to meet targets. Amalberti proposed a similar approach called the sacrificing decisions principle [9].

The aim of the research was to investigate perception towards deviations from procedures and identify reasons leading to deviations in a European military aviation context and to evaluate if operational fields influence the reasons for procedural deviations. It was hypothesized that there would be pronounced differences in the views of the different categories of sharp-end operators, based on SMEs inputs and experience of the researcher in the organization.

2 Method

The selected target sample consisted of sharp-end operators of all qualified and current aircrew, ATC controllers, and maintainers of the organization. They were all active operators (Population = 2098). The members of the target sample were invited by e-mail to participate to the study on a voluntary base by completing a self-report questionnaire based on Hudson et al. [5] and built around sub-scales or clusters, of closed questions organized by the proposed deviation types (i.e., unintentional- Routine- Optimizing-Situational- Exceptional). The participants rated 45 items on a 5-point Likert scale, ranging from “strongly disagree” (1) to “strongly agree” (5), with a neutral answer offered, being “neither agree nor disagree” (3). To account for some military specificities, the instrument was modified by using the word ‘procedure’ (as a generic term to cover guidelines, rules, procedures and work instructions) instead of ‘rule’. References to financial incentives were removed. Open questions on perception of organizational culture, existing set of procedures, deployed operations, and conflicting goals were added to elicit qualitative data. Questions on examples of deviations were part of the open questions. The “Hudson et al.” questionnaire was originally developed for the North Sea Offshore industry. Using it in another industry was perceived as a learning opportunity.

Data were analyzed quantitatively (One-way ANOVA and Tukey HSD as post hoc test, using SPSS). The perception towards deviations per deviation type and personnel categories was compared. Qualitative data were subjected to a Thematic Analysis (TA). The full process of the TA is out of the scope of the present paper/article.

3 Results

A total of 308 participants completed the questionnaire resulting in a total response rate of 14.68%. Information on the sample can be found in Table 1; and the quantitative results in Table 2 hereunder.

Qualitative Data Analysis. Participants responding to the open questions provided in total 20,093 words in their answers. From those answers a total of 881 statements were found as relating to procedural deviations leading to the final selected themes: Procedure, Resources, Mission, Organizational Culture,, Organizational environment (including leadership and supervision). The Thematic Analysis results are expanded in the discussion hereafter.

Table 1. Composition of the sample per personnel category, including response rate, experience, deployment history, and proportion answering open questions in the instrument.

Personnel category	Response rate	N	Provided qualitative data	Experience in years	Ever deployed
Aircrew	17.36%	71	68%	1–3 to 39–42 M = 10–12	88.5%
ATM	12.40%	15	67%	1–3 to 28–30 M = 19–21	66.6%
Maintainers	14.16%	222	54%	1–3 to 39–42 M = 28–30	79.5%

Table 2. Perception towards types of deviations and personnel category on a five-point agreement scale ranging from 1, strongly disagree to 5, strongly agree. Table includes one-way between personnel categories ANOVA results, Tukey HSD when applicable, and effect size per deviation type.

Deviation type	Personnel category	Mean	Standard deviation	ANOVA	Tukey HSD	Effect Size
Unintentional-clarity	Aircrew ATM Maintainers	2.88 2.83 3.25	1.27 0.63 0.62	$F(2,305) = 11.10$ $p < .001$	Maintainers >< Aircrew	$\eta^2 = 0.07$
Unintentional-availability	Aircrew ATM Maintainers	3.17 2.89 3.35	0.67 0.72 0.57	$F(2,305) = 5.657$; $p = .004$	Maintainers >< ATM	$\eta^2 = 0.04$
Routine	Aircrew ATM Maintainers	2.99 2.93 3.21	0.63 0.69 0.62	$F(2,305) = 4.184$; $p = .016$	Maintainers >< Aircrew	$\eta^2 = 0.03$
Situational	Aircrew ATM Maintainers	3.32 2.96 3.57	0.68 0.60 0.67	$F(2,305) = 8.856$; $p < .001$	Maintainers >< Aircrew and ATM	$\eta^2 = 0.055$
Optimizing	Aircrew ATM Maintainers	2.58 2.71 2.68	0.55 0.38 0.47	$F(2,305) = 2.238$; $p = .296$	–	-
Exceptional	Aircrew ATM Maintainers	2.72 2.68 2.99	0.65 0.40 0.61	$F(2,305) = 6.399$; $p = .002$	Maintainers >< Aircrew	$\eta^2 = 0.04$

4 Discussion

The results indicated some statistically significant differences between categories concerning perceptions on procedural deviations. Differences were present for all types of deviations, except for optimizing deviations, and were differences between Aircrew and

Maintainers and/ or between ATM and Maintainers. However, the noticed differences were small. This could be considered as an indication that the views on procedural deviations may be for the most part influenced by the organizational culture, compared to a lower influence of respondents' function and professional culture. The organizational possibly taking over the professional culture was unexpected from experience in the organization, hence further investigation is of interest. In the present research, organizational culture was not formally measured. Replication of the research in another similar military aviation, including a structured measurement of the organizational culture, is recommended. Hudson et al. [5] consider their model as general and propose that the relative importance of the specific factors, or elements influencing the deviations types, depends on the local culture. As a matter of fact, local culture would only influence views in a specific category (Aircrew, ATM, Maintainers) by determining the scores for the considered deviation types. Mc Donald et al. [6] suggested that the professional culture compensate for the deficiencies of the organizational system. The relative unanimity across groups indicated that the cultural influence could be found at a level higher than the local or professional culture of the group. A possible predominance of the organizational culture on professional culture could be explained by the fact that operators from different fields do join the Air Force as from a young age and are all trained for their role inside the organization and do remain in the institution for their entire career.

The rest of the discussion is based on the qualitative data. Most respondents reported issues with the *procedures* themselves. Participants considered them as too numerous, making it impossible to know them all. Operators expect somehow to find themselves cutting corners due to the procedures as they offer many situational opportunities to deviate. Motivated personnel will find opportunities more easily than unmotivated operators [5]. Procedures were reported by Maintainers as being difficult to understand; and referring to other procedures by all categories. Maintainers considered that no system exists to check if people understand procedures before they are used; and Aircrew and Maintainers did report coming across procedures they did not know about. This situation likely influences the mental model operators develop about the tasks they must perform. Woods et al. [7] suggested that bringing knowledge to bear effectively in problem solving and task execution is a process that involves knowledge content, knowledge organization, and activation. Operators confronted with interlinked and difficult to understand procedures will develop their own mental model of the tasks at hand from a 'buggy knowledge' [7]. According to the respondents from all categories, procedures do not always describe the best way of working and infringements of some procedures occur at all time. Those views on procedural deviations show the existing difference between 'work-as-imagined' and 'work-as-done' [4]. The actual conditions often differ from the ideal ones. Operators then engage in a positive procedural adaptation process to get the work done [2][4]. The results illustrated also the different views on procedures adopted by management and operators. Management mainly considers procedures as the key to safety and performance; and strict compliance is expected across the organization. However, on occasions, depending on the circumstances, or conditions, managers do nevertheless support procedures not being followed. Operators on their side rely on professional judgement and competence and less, or not, on formal rules [3] while considering that procedures apply to all and not only the less experienced workers. Hudson et al. [5] proposed 'powerfulness' as a major component leading to deviating behavior. Powerfulness means that operators have the feeling of competence and skill to deviate from procedures based on experience. Deviations are in some situations unavoidable and recognized as such by operators and management. Hudson et al. [5] categorized this component of deviating behavior as 'powerlessness', where there appears to be no choice. Respondents did put some negative label forward regarding deviations but recognized that they are necessary to keep the job going.

The Aircrew and Maintainers reported a lack of available *resources* (personnel, equipment) as influencing the need to deviate. To meet organizational targets, operators develop alternative methods sometimes becoming routine practices and norms. The expectation of having to deviate from procedures lowers again the threshold for deviating. Hudson et al. [5] consider that 'expectation' influences deviating behavior by lowering the threshold of deviating.

The more important the *mission* is perceived by operators the more they are driven to succeed. The most important missions were identified as being delivering an operational payload, medical evacuation and (V)VIP flights. This attitude directly influences powerfulness and motivation, and subsequently procedural deviations. The actual situation or conditions, when differing from the assumptions made for procedure development, lead to deviating from procedures. Unplanned and unanticipated dynamically changing situations lead to possible deviations. Maintainers reported that time pressure was the main driving factor behind procedural deviations linked to the situation. No specific mission importance was reported by engineers. Time pressure is not influenced by how important the mission is. The Efficiency-Thoroughness Trade-Off proposed by Hollnagel [4] come here into play. However, time pressure (induced by improper or unstable planning) generates goal conflicts in operators as they then must choose between safety and efficiency.

The *organizational culture* based on initiative, flexibility, and safety was described by participants from all categories as a 'can do culture'. Operators are driven by the desire to meet the organizational targets. As from the initial stage of training, autonomy and initiative are emphasized (especially for the Aircrew category). Therefore, being motivated and goal oriented, despite working in an organization tending to be ultra-safe as proposed by Amalberti [9] leads to procedural adaptation and can make those becoming a common practice. Dekker [2, 8] considers procedural adaptation as an essential principle for organizational evolution and success.

At the *organizational environment*, leadership and supervision level, a 'disconnection' between management and operators was reported, illustrating the different views on procedural compliance. Operators reported perceiving direct or indirect pressure to deviate from procedures, inducing conflicting goals and leading them to trade-offs The ATM respondents reported that conflicting goals or conflicts of interest might emerge from military ATM peculiarity as the organization is simultaneously 'regulator' and 'service provider'. Woods et al. [7] propose that multiple, simultaneously active goals are the rule rather than the exception for domains where expertise is involved. Conflicts arise from the relationships between different goals. Competition between goals generated at the organizational level can be an important factor in the breakdown of safety barriers; and operators are facing a responsibility-authority double bind when they have the responsibility for the outcome but lack the authority to take the actions they see as necessary [7].

Throughout the study, respondents from all groups, reported an increase in deviations during deployed operations due to different combining factors, such as individual factors like the drive to succeed, lack of resources, the conditions being different from the procedure's assumptions. Deployed operations can be considered as a catalyst for procedural deviations and illustrate further that the actual circumstances have a definite impact on procedural deviations.

5 Conclusion and Summary

The perception towards procedural deviations across the considered categories (Aircrew, ATM, and Maintainers showed little differences contrary to initial hypotheses. In our sample the organizational culture may take precedence on professional culture when considering procedural deviations. The identified motivations for deviations in the studied military aviation organization were the procedures themselves, the perceived importance of the mission, the actual conditions, the organizational culture, the lack of resources, individual differences; and the organizational environment, including leadership and supervision.

Deployed operations act as a catalyst for most deviation types in a military organization when the deployed personnel must adapt and move from an ultra-safe model organization to a resilient model organization.

Deviating from procedure is commonly negatively connoted and was reported as such by most of the respondents. The negative judgmental approach to deviations based on visible negative outcomes masks the reality of all the daily procedural adaptations and trade-offs made by operators to successfully meet the organizational targets. Although the considered organization invests resources in personnel training on relevant operational tasks, procedural deviations are left to the individual in the organization; left on their own and trying to make the best out of their knowledge and judgement. The organization might benefit from a structured "deviation education" aiming at integrating for example risk management, crew or maintenance resource management, and decision-making education to improve performance and resilience of the organization. Furthermore, replicating the research in similar military aviation organizations is recommended to develop specific knowledge on such institutions and identify the influence of organizational culture on procedural deviations in military aviation.

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Prevention Through Design: Clients' Pre-construction Health and Safety Arrangements

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Abstract. Proactive management of health and safety risk often minimises ill-health, injuries and fatalities on projects. Hence, in some jurisdictions like the UK, statutory duties are placed on project Clients to make suitable arrangements for projects to be carried out without risk to health and safety. This study surveys Clients and practitioners in the UK construction industry in focus group workshops to establish seven dominant practices being employed by Clients in response to this obligation under the health and safety Regulations.

Keywords: Design for occupational health and safety · Pre-construction · Project clients · Health and safety arrangement practices · Construction

1 Introduction

The nexus between procurement and design decisions upstream of the construction supply chain and occupational safety and health (OSH) risks downstream of same has been articulated in literature and practice for many decades. This connection was informed by the lack of proactiveness on the part of parties of the construction supply chain, particularly parties upstream of the chain, in managing construction risk and the resultant poor performance of OSH risk management on construction projects [1–5]. There is therefore a call by scholars and practitioners for project stakeholders to accept responsibility, collectively, to minimise OSH risks on construction projects with the view that such an obligation must start from the commencement of the construction product development process [2, 4, 6, 7]. This understanding underpins the Prevention through Design (PtD) philosophy [1, 2].

The PtD philosophy informed the European Council's response to the OSH challenges of the construction industry with the adoption of Council Directive 1992/57/EEC on the implementation of minimum safety and health requirements at temporary or mobile construction sites. In 1994, the UK which was then a full member of the EU,

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transposed the Directive into UK legislation as part of the Construction (Design and Management) Regulations 1994 (CDM 1994). These Regulations have since been revised twice with the current version being CDM 2015. The Regulations impose statutory health and safety duties on the traditional members of construction project stakeholders (clients, designers and contractors) to ensure that the design and production of construction products are carried out without risks to health and safety. Clients as initiators and purchasers of construction products have dominant positions on projects to influence OSH risks on projects [8, 9]. Hence, the CDM 2015 Regulations require clients to make necessary health and safety arrangements to ensure projects are inherently safe. However, the Regulations are not clear as to what specific practices should be embarked on by clients in compliance with this requirement. Thus, this study focuses on the pre-construction phase of the project development process to explore the range of practices in place, in the UK construction industry, regarding clients' health and safety arrangements as required by the Regulations.

2 Method

The study employed a qualitative research approach in undertaking this probe. A qualitative research approach is considered suitable for studying a phenomenon, including obtaining data in the form of verbal conversion from a relatively smaller number of individuals so as to capture their views on a situation [10].

Specifically, data was obtained through fourteen focus group discussions (FGDs) over a period of six weeks with over seventy practitioners in the UK construction industry with backgrounds as clients, designers, contractors as well as health and safety professionals. A FGD approach was employed, because the study's aim was to: understand and not infer; determine the range of views and not generalize; and offer insights into how the research participants recognise health and safety arrangement practices by clients – particularly at the pre-construction phase – in response to regulatory requirements [11].

The participants for the focus group workshops were purposively selected from the UK construction industry. This offered the researchers opportunity to obtain participants who were *information-rich* and could offer relevant information regarding the phenomenon being investigated [10, 12]. This study formed part of a larger investigation on how, generally, the UK construction industry complies with construction health and safety regulations and thus had partnership with professional bodies and industry partners. As a result, to recruit participants for the FGD workshops, leadership of the professional bodies and industry partners were contacted to publicise the FGD workshops within their networks. Interested participants were subsequently written to and subsequently made to complete a consent form to join the FGD workshops. Each FGD workshop was recorded to capture a vivid discussion of the session.

The data analysis process involved: (a) transcription of the FGD recordings, (b) critical reading of the transcripts to gain insights of main patterns embedded in the data, (c) loading of FGD transcripts into Nvivo version 12 software programme, (d) generation of codes and categories based on the study aim by means of an inductive coding strategy in an Nvivo environment, (e) development of higher order themes through clustering of lower level categories [13].

3 Results and Discussions

A word cloud of the 75 most frequently used words during the FGD workshops was initially produced (Fig. 1). The diagram provides an overview of the different words and frequency of use (as revealed by the size) in the FGD workshop data. Though the participants reflected their experiences regarding Clients health and safety arrangements or practice, they often expressed their views with the word *I think,* highlighting the subjectiveness embedded in qualitative inquiry [10]. *Yeah* was used frequently in the FGD workshops by the participants in support of colleague participants' views of indicated practice and as a reflection of the high degree of agreeableness among workshop participants.

Fig. 1. Word cloud diagram of 75 most used words in the FGD workshops

As indicated in Table 1 and the *project map* in Fig. 2, the health and safety arrangements of Clients, in the UK construction industry, in response to CDM Regulations 2015 are classified into seven categories as: dependence on third party health and safety arrangements such as Principal Designers, CDM advisors, and health and safety consultants; reliance on in-house health and safety teams and systems; early project collaboration meetings; health and safety agenda setting through client brief; reliance on project managers; use of contractual arrangements between project participants; use of in-house health and safety teams and structures with support from external health and safety consultants.

Table 1. Categories of Clients' health and safety arrangement practices in compliance with CDM 2015

Categories	Sub-categories
Dependence on third party health and safety arrangements such as Principal Designers, CDM advisors, and health and safety consultants	• Appointment of CDM advisors to perform Client roles (19) • Use of Principal Designers (PDs) (16) • Use of health and safety consultants (3)
Reliance on in-house health and safety teams and systems	• Design management plan or CDM management plan (13) • Setting up of in-house health and safety team (7) • Development of health and safety policy (2) • Development of loop system to utilise design health and safety feedback • Award scheme for best health and safety practice or innovation
Early project collaboration meetings	• Client CDM introduction meeting among project participants prior to commencement of design (5) • Client pre-construction rehearsal and constructability review meeting before construction phase
Health and safety agenda setting through client brief	• CDM strategy brief (3) • Client brief (2)
Reliance on project managers	• Project manager coordinating design review meetings on behalf of Client (2) • Project manager listed as Client and assuming Client health and safety duties
Use of contractual arrangements between project participants	• Health and Safety duty requirements in terms of appointment of project parties • Client inclusion of site visits terms in appointment contracts of contractors
Use of in-house health and safety teams and structures with support from external health and safety consultants	• Client internal team carries out Principal Designer role with support from health and safety advisors • Project development and design managers in charge of health and safety with external advisory support

Note: Figures in parentheses denote the number of references to such practices by the FGD workshop participants

3.1 Dependence on Third Party Health and Safety Arrangements such as Principal Designers, CDM Advisors, and Health and Safety Consultants

Under this practice, Clients often engage the services of other entities (PDs, CDM advisors, and health and safety advisors) competent in the management of OSH on construction projects to assist them to fulfill their health and safety duties under Regulations. PDs are required by the Regulations, particularly for projects involving more than one contractor on site, to be appointed by the Client to coordinate project health and safety matters at the pre-construction phase of the project development process. On the other hand, CDM advisors as well as health and safety consultants have no such statutory roles under the Regulations. As part of Clients duty to make suitable arrangements for the management of projects without risk to health and safety, Clients often fall on these third party entities to among other things, advise Clients or make them aware of their duties under the Regulations; take active roles in the preparation of relevant pre-construction information and their subsequent dissemination to relevant project parties for optimal OSH decisions along the project supply chain; and advising clients on the appointments of project parties with relevant health and safety skills, knowledge and experience or organisational capability. As shown in Table 1, this practice appears to be most common approach in the industry with the most references by the FGD workshops participants. 19 and 16 references for the appointment of CDM advisors to perform Client roles and use of Principal Designers, respectively.

3.2 Reliance on In-House Health and Safety Teams and Systems

Informed project Clients often have well established in-house health and safety teams and systems for ensuring that the Client's duty of making suitable arrangements for projects is complied with under Regulations. Such a practice, as indicated in Table 1 includes a number of approaches. First, Clients develop design management plans or CDM management plans as part of measures to comply with their duties under the Regulations. The design or CDM management plans basically considers what the Client and other dutyholders duties are and what the Client needs to do to ensure all dutyholders are fulfilling their duties under the Regulations. A checklist is made of them as a control document during the management of health and safety matters at the pre-construction phase of the project development process. This, in addition to the appointment of CDM advisors and use of PDs, seems to be a popular practice with a reference of 13 by the workshops participants. Second, Clients set up core in-house health and safety teams to support the preparation of pre-construction information and coordinate all health and safety processes at the pre-construction phase of the project development process. This practice is often common with large infrastructure firms which have such departments embedded in their corporate structures. Third, health and safety policies and CDM manuals are developed and enforced among project parties by Clients as ways of making appropriate health and safety arrangements for projects. Fourth, some project Clients have feedback and loop systems to capture learning and lessons on prior designs and construction to benefit current and future project designs and implementation. Further, as a way of encouraging the right behaviours and decisions in respect of OSH among project parties, particularly at the pre-construction stage, some Clients have instituted

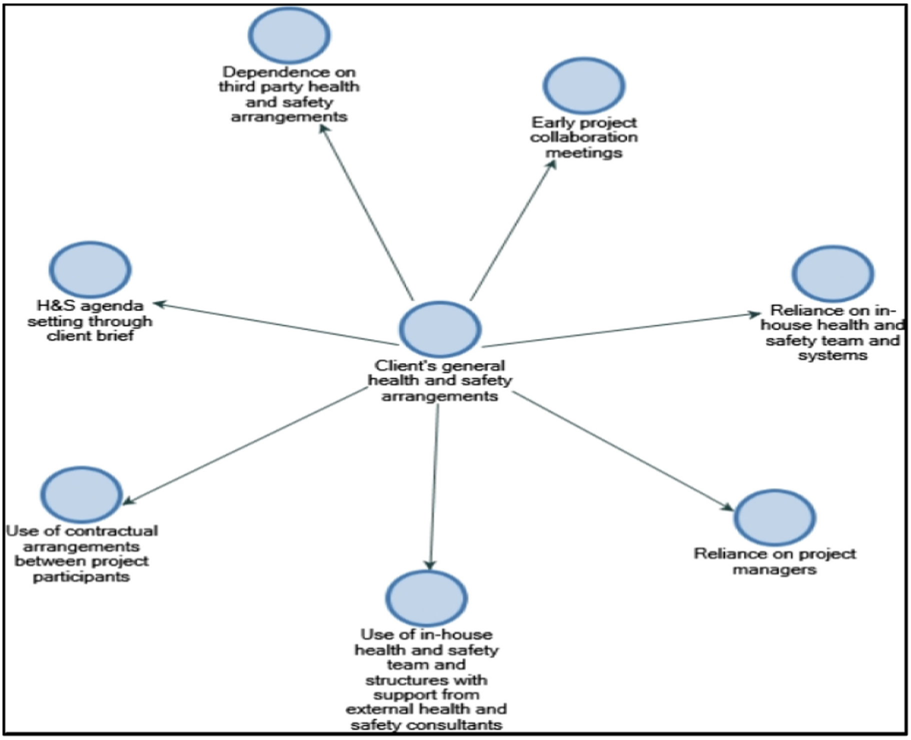

Fig. 2. Project map of clients' pre-construction health and safety arrangements categories

internal and innovation award schemes. These last two practices (loop or feedback system and OSH award schemes) appear not to be common in the industry and are still at the embryonic stage.

3.3 Early Project Collaboration Meetings

In compliance with the Regulations to make suitable arrangements so projects can be carried out without risk to health and safety, some Clients act proactively and organize two meetings at the pre-construction phase to orient parties along the project supply chain in respect of OSH. These meetings include Client CDM introduction meeting among project participants prior to commencement of design and Client pre-construction rehearsal and constructability review meeting immediately before the construction phase.

3.4 Health and Safety Agenda Setting Through Client Brief

As indicated in Table 1, this practice comes in two forms. Use of Client brief and CDM strategy brief as part of the tools for ensuring suitable health and safety arrangements on construction projects by Clients. The Client brief is the expression of the Client requirements regarding the development of the construction project and often in there, Clients indicate their aspirations and commitments regarding health and safety management to provide direction from the outset of the project development process. This document generally is from the Client to the lead designer. However, to provide further details of project OSH risks and to ensure somewhat inclusiveness among project parties upstream of the supply chain, currently a CDM strategy brief has been introduced. This document often receives inputs from the Client, the lead designer, the PD, and any other project party appointed. In addition to the general Client requirements and how the project will be managed, this document also identifies and indicates key project hazards and OSH risks to support the optimal health and safety decisions of parties along the project supply chain.

3.5 Reliance on Project Managers

Another variant of practice regarding Clients health and safety arrangements for projects is Clients' dependence on project managers. This practice manifests in two forms as Clients relying on project managers to convene and coordinate design review meetings as well as Clients listing project managers as Clients and letting them assume Clients health and safety duties on projects. Under this practice, Clients assume that project managers have requisite health and safety skills, knowledge and experience or organisational capability, which is often not the case. This can undermine project OSH risk management performance.

3.6 Use of Contractual Arrangements between Project Participants

Clients employ contractual measures, as part of suitable project health and safety arrangements, to have project parties comply with Regulations for optimal OSH risk management performance on projects. Hence, specific health and safety requirement terms are included in the contracts of appointments of project parties. This gives power to the Client to effectively control activities of project parties, particularly from a health and safety perspective.

3.7 Use of In-house Health and Safety Teams and Structures with Support from External Health and Safety Consultants

Depending on the capability of some Clients, there is often the practice of blending both internal and external competence regarding Clients' suitable health and safety arrangements on projects. This normally takes the form of Client internal team carrying out Principal Designer role with support from health and safety advisors as well as in-house project development and design managers being in charge of health and safety with external advisory support.

4 Conclusions

The role of Clients in ensuring optimal OSH risk management performance on projects cannot be discounted. Hence Regulations place Clients at the centre of affairs regarding the management of health and safety by requiring them to make suitable arrangements for projects such that work can be carried out without risk to health and safety. The practices Clients adopt to comply with this duty, as required by the Regulations, are not clear in construction health and safety management literature. This study has sought to empirically unearthed seven main practices by which Clients make arrangements for project health and safety with the dominant one being dependence on third party health and safety arrangements such as PDs, CDM advisors, and health and safety consultants. The identified range of practices serves as a guide for most clients who are faced with uncertainty as to how to comply with the Regulations from the perspective of pre-construction health and safety arrangements.

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Understanding Systemic Interactions and Feedbacks in a One-Health

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Abstract. Food safety and occupational health problems, when occur, usually as episodic and isolated events, often overlapping one to other. Hence the challenge is to make the interconnectivity of processes and anthropogenic influence understandable. Antimicrobial Resistance (AMR) monitoring in zoonotic and commensal bacteria in animal-related occupations and food should be connected to occupational biological risk assessment. While many people may be willing to accept the plausibility of the above example, it is more complex to make them understanding that all activities interacting in the workplace imply an increased risk to workers. As small and medium-sized enterprises are the most common in agriculture and food sector AMR is not a concern in risks prevention. Salmonellosis has been one of the most common disease regarding zoonoses in Europe and concerning to AMR, the latest data from humans, animals and food reveal that a large proportion of Salmonella spp. bacteria are multidrug-resistant. The occupational safety professional is always facing gaps in hazard assessment of the risks engendered by zoonoses due to the lack of information on biohazards in the workplace.

Keywords: AMR · Food safety · Occupational health · One health

1 Introduction

One Health is a collaborative, multisectoral, and transdisciplinary approach working at local, regional, national, and global levels to achieve optimal health and well-being outcomes. Recognizing the interconnections between people, animals, plants and their shared environment that can contribute to the emergence, evolution and spread of antibiotic resistance and the health of these contiguous habitats, and may represent a risk to public health [1, 2]. This terminology was first used in 2003–2004 [3] and remains so relevant and timeless. It has become increasingly clear, over the past decades, that the majority of zoonoses, foodborne outbreaks or antimicrobial resistance (AMR) cannot be dissociated from biological risks exposure. A collaborative and multi-disciplinary approach, prioritizing interventions and cutting across boundaries of animal, human, and

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environmental health, is needed [4, 5] and biological risk assessment in a One-Health perspective should be undertake.

In 2007, occupational risks related to global epidemics and emergence of drug-resistant organisms were mentioned by the "European Agency for Safety and Health, at Work's Expert Forecast on Emerging Biological Risks related to Occupational Safety and Health", the first and second most important emerging risks. In 2021, we are living a pandemic caused by SARS-CoV-2 and AMR is, nowadays, one of the biggest threats to global health, food security and development [6, 7]. Worldwide, an estimated 320,000 workers die annually from work-related infectious diseases, 5,000 of whom in the EU [8]. Biological risk assessment is usually neglected by the occupational health professionals due to the lack of systematized information about the biological agents involved [9]. In consequence, risks engendered by zoonoses and AMR, in the food sector and in the primary sector (a world where small and medium-sized enterprises account for the majority of businesses), are not included in the risk assessment. With this concern in 2017, European Food Safety Authority (EFSA) and member state authorities carried out a study by tackle the risks posed by the use of antibiotics and AMR in animal population's, and their links to human health to gather evidence about some topics such as: i) risk perceptions on the human health impact of antimicrobial resistance in animals; ii) risk for occupational groups (e.g. veterinarians, farmers, meat handlers); iii) risk of transmission of antibiotic-resistant bacteria to consumers via food [10]. High-risk occupations are regarding animal-related occupations and arable farming [8].

2 Exposure to Multiple AMR Bacterial Pathogens

The administration of therapeutic and sub-therapeutic doses of antimicrobials in animals, including the nontherapeutic use of antimicrobials (to improve feed efficiency and prevent infection), leads to the propagation and shedding of substantial amounts of antimicrobial-resistant bacteria—both pathogens, which can directly and indirectly infect humans, and commensals, which may carry transferable resistance determinants across species borders and reach humans through multiple routes of transfer [11, 12]. It also has implications for both, food safety and food security and the economic wellbeing of millions of farming households. Food chain plays an important role in the development and spread of AMR. The presence of AMR microorganisms in agricultural production systems and food chains are potential routes of exposure for everyone [13]. How can we relate the use of antimicrobials in primary production (livestock and agriculture) with food production and retail? Food processing uses products from primary production that were exposed to antibiotics and biocides (e.g., disinfectants, food and feed preservatives, or decontaminants) with therapeutic effects (or not) in primary production and then go to retail. In other words, taking this cycle into account, we have occupational exposure to AMR bacteria in all stages of the food chain and, *a posteriori*, the consumption of contaminated food or with antibiotic residues. Ingestion of contaminated food can give rise to an infection that must be treated and the human is in contact with AMR bacteria and the therapy may be compromised. Ingestion of food with residues of antibiotics affects the microbiome of humans with the incorporation of AMR bacteria.

Strategies aimed at reducing or minimizing the emergence and dissemination of antimicrobial resistance in primary production, food processing and retail is a top priority. Although the number of interventions for antimicrobial resistance is increasing but current research has major limitations in terms of efforts, methods, scope, quality, and reporting [14].

2.1 Salmonellosis

Salmonella spp., is a Gram-negative bacterium belonging to the *Enterobacteriaceae* family and currently includes only two species with more than 2,600 serovars and is responsible for a disease called Salmonellosis [15, 16].

Salmonella enterica serovars Typhi, Paratyphi A, Paratyphi B, and Paratyphi C may be referred to collectively as typhoidal *Salmonella*, whereas other serovars are grouped as nontyphoidal Salmonella (NTS) [17]. Regarding to AMR, the latest data from humans, animals and food show that a large proportion of *Salmonella* bacteria are multidrug-resistant (resistant to three or more antimicrobials). Workers in contact with animals have a highest risk of infection by a variety of *Salmonella* serovars since the overall and high antibiotic use in food-producing animals have an impact on the occurrence of resistance and that most antimicrobial-resistant *Salmonella* infections are acquired from eating contaminated foods [18, 19].

In humans, NTS *Salmonella* strains may be host generalists, infecting or colonizing a broad range of animals, or tend to be host-specific to particular animal species and is transmitted predominantly by commercially produced food contaminated by animal feces, and it usually causes a self-limited enterocolitis with diarrhea non-typhoidal. Whereas typhoidal salmonellas are human host-adapted organisms that cause typhoid fever and paratyphoid fever and is transmitted predominantly through water or food contaminated with human feces and human host-adapted organisms that cause typhoid fever and paratyphoid fever [17].

Human salmonellosis is usually characterized by acute onset of fever, abdominal pain, nausea, and sometimes vomiting, after an incubation period of 12–36 h. Symptoms are often mild, most infections lasting a few days, but, in some patients, the infection may be more serious and the associated dehydration can be life-threatening. When Salmonella causes systemic infections, such as septicemia, effective antimicrobials are essential for treatment. Salmonellosis has also been associated with long-term and sometimes chronic sequelae, e.g. reactive arthritis. Mortality is usually low, and less than 1% of reported Salmonella cases have been fatal [20].

Antimicrobial resistance is increasing in *Salmonella* strains, a finding that has important public health implications and the antimicrobial drugs to which food animals are exposed provide selective pressure that leads to the appearance and persistence of resistant strains [19].

Salmonellosis is the second most common zoonotic disease after Campylobacteriosis in the EU, and the overall economic burden of human salmonellosis could be as high as €3 billion a year [21]. Although, regarding data on human Salmonellosis infections the numbers presented in Table 1 may have a *bias* due to the lack of harmonization in reporting the data in the earlier years by the EU Member States, but it can be seen a reduction in the occurrence of the disease around 40% between 2008 and 2019 years.

Between 2008 and 2019, most of the reported total foodborne outbreaks were caused by *Salmonella* spp., and only in 2014 the largest number of reported food-borne outbreaks was caused by viruses (20.4% of all outbreaks), which overtook Salmonella (20.0% of all outbreaks) as the most common cause of outbreaks in the EU.

Table 1. Evolution of salmonellosis in humans and total foodborne outbreaks

Year	Cases in humans	Foodborne outbreaks	Source
2008	131,468	5,332	[22]
2009	108,614	5,550	[23]
2010	99,020	5,262	[24]
2011	95,548	5,648	[25]
2012	91,034	5,363	[20]
2013	82,694	5,191	[26]
2014	88,715	5,251	[27]
2015	94,625	4,362	[28]
2016	94,530	4,786	[29]
2017	91,662	5086	[30]
2018	91,857	5,363	[18]
2019	88,000	5,175	[31]

Additionally to zoonotic diseases and foodborne outbreaks, the expansion of antibiotic resistance determinants among human, animal and environmental microbiomes have the potential to alter bacterial population genetics at local and global levels, thereby modifying the structure, and eventually the productivity, of microbiomes where antibiotic-resistant bacteria can expand and thereof AMR has become a major threat worldwide, especially in countries with inadequate sanitation and low antibiotic regulation [2, 5].

Since 2005 EFSA first and then joined with ECDC reports data on AMR in Salmonella from humans, animals and food. In January of 2021, EFSA published a guidance for reporting 2020 antimicrobial resistance in food-producing animals and foodstuffs derived thereof to harmonise and streamline the reporting made by the Member States to ensure that the antimicrobial resistance data collected are relevant and easy to analyse at the European Union level. This guidance also applies to *Salmonella* spp. and it is mandatory to report at the serovar level but reporting the phagetypes of *Salmonella Enteriditis* and *Salmonella Typhimurium* is optional. The mandatory antimicrobials to be reported are: Ampicillin, Azithromycin, Cefotaxime, Ceftazidime, Chloramphenicol, Ciprofloxacin, Colistin, Gentamicin, Meropenem, Nalidixic acid, Sulfamethoxazole, Tetracycline, Tigecycline and Trimethopri. All randomly selected isolates of *Salmonella* spp. recovered from non-selective media, that are resistant to cefotaxime or ceftazidime or meropenem, are further tested with a second panel of antimicrobial substances Cefepime, Cefoxitin, Ceftazidime, Ceftazidime + clavulanic acid, Cefotaxime, Cefotaxime + clavulanic acid, Ertapenem, Imipenem, Meropenem and Temocillin [32].

AMR in non-typhoidal Salmonella and Salmonella serovar Typhimurium has been studied in animals, such as poultry, swine and cattle, humans and the environment [33–40]. Santos et al. (2020) reported the lack of harmonization of methodologies to research and count biological agents was notorious [9] and the same can be mentioned to AMR detection although EU in Commission Implementing Decision 2020/1729[1] in accordance with Directive 2003/99/EC[2] the antimicrobial susceptibility testing shall be performed by using the broth micro dilution method according to the reference method ISO 20776–1:2019 or Member States may decide to authorize the use of Whole Genome Sequencing ('WGS') as an alternative method to broth micro dilution using the testing panels of antimicrobial substances[3].

2.2 AMR and Occupational Biological Risk Assessment

In food industry there are several stages in the chain that guarantee the quality of the final product that will be consumed. From primary production to retail mandatory official controls to food business operators, good hygiene and manufacturing practices and HACCP. In addition, in Europe there are specific regulations covering the monitoring and reporting of AMR bacteria but harmonized and immediate actions on a global scale are needed to mitigate AMR burden and prioritization of AMR control interventions is essential for optimal allocation of risk management attention, particularly in resource-limited settings [5].

Training and awareness-raising was recognized as particularly important in SMEs, (arable and livestock farming) but they are difficult to reach once often they have less financial means to implement control measure to undertake a risk assessment, and to develop plans for response and control [8].

However, to our knowledge, the risk assessment of exposure to AMR bacteria is never reported in risk analyzes or included in risk management plans in occupational health. "One Health" is as an interdisciplinarity approach that occupation health professionals are not familiarized. In a simple search on the websites of EU-OSHA or USA-OSHA there isn´t any mention to "one health" plan of action.

3 Conclusion

Biological risk assessment itself is an issue that has not been evaluated by occupational health and safety professionals due to the lack of information and consciousness on the subject, and exposure to AMR is even more neglected. As a major worldwide AMR threat management of biological agents may be challenging for SMEs, given their lack of knowledge and awareness.

[1] OJL 387/8, 17.11.2020, p16.
[2] OJ L 325, 12.12.2003, p. 31.
[3] OJL 387/8, 17.11.2020, pp. 16–19.

Moving the agenda forwards requires an improved understanding of the diversity of interventions and underpin their effectiveness, considering the different regulations in each country. Biological risk assessment in a One-Health perspective should be undertake and to develop plans for response and control there is a strong need to better educate occupational health professionals in biological agents and bacterial antimicrobial resistance.

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Management and Control of Occupational Risks in the Manufacture of Fuel and Oil Filter Caps

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Abstract. In the process of manufacturing oil and fuel filter covers, mechanical risks have been identified such as: entrapment and crushing of hands with risk level I (not acceptable) and projection of fragments and particles with risk level II (Not acceptable or acceptable with specific control); For this, corrective measures were established at the source of risk by means of a spring system in each of the molds so that the filter cover after being pressed is expelled uniformly without the need for the operator to insert his hands in the danger zone. In the accident transmission medium, an adjustable safety guard and a mechanical guide element were implemented which allow the entry and exit of the covers. Finally, workers were provided with work gloves selected under international standards.

Keywords: Hand entrapment · Risk source · Accident transmission medium · Worker safety · Industrial safety

1 Introduction

Occupational accidents and occupational diseases annually cause more than 2.78 million deaths, 2.4 million of those deaths are related to diseases, and about 374 million workers are victims of non-fatal work accidents [1].

According to the occupational accident distribution in Ecuador, these injuries are mostly superficial, like contusions, and dislocations. Primarily affecting the upper limbs or appendages such as hands, arms, and forearms. Traumatic amputations are not common but they damage the operators permanently is the entrapment of the operator or some part of his body in the fixed or moving mechanisms of a machine, causing contusions, trauma, sprains, fractures, wounds, cuts, and even amputations that, without proper medical attention, can result in death [3].

The oil and fuel filter cap manufacturing process exposes operators to multiple risks. Due to the machine's characteristics, the pressing operators' probability of having an accident is high. Thus, it is of the utmost importance to identify the causes and consequences of accidents during the oil and fuel filter cap manufacturing process in ad-vance. Risk assessment, and corresponding control to mitigate them during the production process so that it is safe to manufacture oil and fuel filter caps. The aim of this re-search is to propose corrective measures to control occupational hazards during the oil and fuel

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filter cap manufacturing process by identifying their causes and consequences, the level of deficiency, exposure, and the probability of risks for their respective management at the risk source, transmission path and receptor.

2 Analysis and Design

2.1 Analysis

The hazard identification and assessment of occupational safety and health risks guide (GTC 45) presents an integrated framework of principles, practices, and criteria for assessing risks in operator activities in order to conduct appropriate management by analyzing the existence of controls at the risk source, the transmission path and the receptor; risk level deficiency, risk exposure, probability, consequences, and intervention to categorize them as acceptable or not [4].

2.2 Corrective Measures Design at Risk Source Level

For risk source management, four equidistant springs will be placed in the press dies so that the ASTM A36 steel sheet metal, which mechanical properties are presented in Table 1, can be pressed and removed uniformly, thus enabling the operator to work without exposing the operator's hands to the risk source.

Table 1. ASTM A36 steel properties

Quality	Minimum yield strength (Fy)	Tensile breaking stress (Fu)	Minimum elongation	Fy/Fu
ASTM A36	250 [MPa]	400 [MPa]	20%	≤0,85

There are three forces in the pressing process: 1. the cutting force (FC) is one that is ap-plied perpendicularly to the longitudinal axis of the element to be cut, 2. the extraction force (Fext) is required to separate the metal sheet from the punch and 3. the ejection force (Feje) is required to eject the cut section of the sheet out of the matrix as shown in Fig. 1.

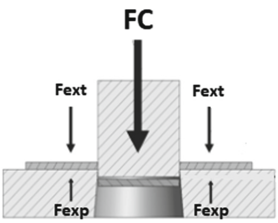

Fig. 1. Forces diagram

The selected springs will be subjected to compression, shear stress due to the perpendicular force applied, and a torque. It should be noted that the ends of these elements are square flat and rectified so that when the plate is pressed, the spring does not leave marks on the sheet.

$$\tau = ks\left(8F.D/\pi.d^3\right)$$

- τ. Stress
- *ks*. Shear stress correction factor
- *F*. Force applied to the spring
- *D*. Spire mean diameter
- *d*. Wire diameter

2.3 Corrective Measures Design at the Transmission Path Level

Machine guards are physical barriers that stand between the operator and the danger zone to prevent the operator from inserting his limbs during the machine operation [5], according to the working conditions of the oil and fuel filter cap manufacturing process, the presence of a fixed machine guard is necessary, which will be supported by two steel columns to provide greater rigidity and strength attached to the machine bench; the slenderness ratio between the column length and the cross-section is expressed as follows:

$$L/r = \sqrt{\left(\pi^2.E.k\right)}/\sigma_{LP}$$

- *E*. Elastic modulus
- *K*. Machine condition dependent constant
- $\sigma_{LP..}$ Yield stress

The working stress consists of the maximum tension divided by a safety factor to consider-er effects on the structure.

$$\sigma_w = \sigma_{cr}/f.s$$

- $\sigma_{cr.}$ Critical stress or strain
- *f.s.* Safety factor

Additionally, to protect the operator from the risk of hand entrapment and crushing, a grooved mechanical element has been implemented that puts the material to be cut in place, and the entry of the worker's upper limbs is not required when manufacturing oil and fuel filter caps.

2.4 Corrective Measures Design at the Receptor Level

Protective gloves are personal protective elements designed to protect the operator from occupational hazards; according to UNE-EN ISO 2388:2016. There are guidelines to choose safety gloves according to their properties, cut resistance, and performance levels. [6] (Table 2).

Table 2. Benefit levels

Description	Measurement units	Level 1	Level 2	Level 3	Level 4
Abrasion resistance	Ciclos	100	500	2000	8000
Blade cut resistance	Index	1,2	2,5	5	10
Tear resistance	Newtons	10	25	50	75
Puncture resistance	Newtons	20	60	100	150

3 Results and Discussion

3.1 Corrective Measures at Risk Source Level

Table 3 shows the cutting, ejection, extraction, and corresponding forces for each spring.

Table 3. Variable force results

Variables	Mold 1	Mold 2	Mold 3	Units
Diameter	18	57	45,5	mm
Perimeter	56,55	179,07	142,94	mm
Sheet thickness	0,7	0,7	0,7	mm
Cutting force	1614,24	5111,77	4080,45	Kgf
Extraction force	113	357,82	285,63	Kgf
Ejection force	24,21	76,68	61,21	Kgf
Force required for each spring	6,05	19,71	15,30	kgf

According to Table 3, the springs that meet the mandatory requirement according to the load were chosen, a Standard series LC 032BB 05 spring of 4.78 mm outside diameter with a load of approximately 6,399 for the first mold, a Standard series LC 032BB 05 spring of 4.78 mm outer diameter with a load of approximately 20,257 kgf for the second mold and a LC 059E 02 spring with a load of 15.90 kgf for the third mold being the re-quired force to put all spring spires in contact. Subsequently, the proposed variables are calculated for each of the selected springs (Table 4).

3.2 Corrective Measures at the Accident Transmission Medium

The maximum opening width of the holes in the safety guard will be 1/4 to 3/8 inch.

Moreover, a 190 mm by 560 mm galvanized wire woven mesh will be made in the shape of small frames allowing the operator to see the pressing of the metal sheet through it. These measures are good enough to cover the workspace, below there are the results of the variables considered in the design of corrective measures at the transmission path level (Table 5).

Table 4. Variable springs results

Variables	Mold 1	Mold 2	Mold 3	Units
Spring length	12,70	12,70	12,70	mm
External diameter	4,78	12,19	9,15	mm
Average diameter of the loop	3,97	10,36	1,83	mm
Coil diameter	0,81	1,83	1,50	Mm
Active turns	5	3	3	u
Total turns	7	5	5	u
Spring index	4,90	5,66	5,10	
Effort correction factor	1,10	1,09	1,10	kgf
Force applied to spring	6,399	20,257	15,9	kgf
Force applied to spring	134,14	94,90	100,77	Kgf/mm^2

Table 5. Variable results security guard

Variables	Symbology	Outcome	Units
Slenderness ratio according to materials	L/r	44,43	u
Slenderness ratio according to geometry	r	7,29	u
Work effort	σ_W	130,21	MPa
Critical load	Pcr	10,55	KN
Workload	Pw	5,49	KN

The sizing of the sliding guide of the metal sheets to be pressed will be 121 mm long, 130 mm wide, and 50mm high, with three sections delimited by the dimensions of the caps to be pressed, the first one of 121.2 mm × 12mm; the second one 73.2 mm × 12mm and the third one 70.7 mm × 12 mm (Fig. 2) and (Table 6).

Table 6. Variable results of sliding guide

Variables	Symbology	Outcome	Units
Weight	w	61,8	N
Shear	V	61,8	N
Bending moment	M	-3,74	Nm

An outline of the proposed design is presented below.

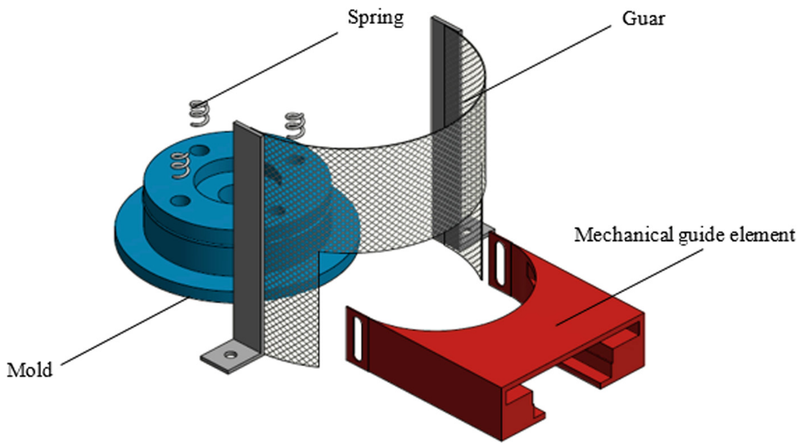

Fig. 2. Proposed scheme

3.3 Corrective Measures at the Receptor Level (Worker)

Under Worker Safety and Health and Environmental Improvement regulations [7] Title VI. Personal Protection, Article 181.- Protection of the upper extremities mentions that different material gloves will be used for work involving cutting, puncture, and impact risks. This personal protective equipment must be flexible, allowing the normal motion range of the protected area. In this case, because during the cap pressing process, the operator is exposed to mechanical hazards such as the entrapment and crushing of hands, the personal protection equipment for upper limbs will be selected in accordance with the standard UNE-EN ISO 388:2016, with the following characteristics:

Table 8 shows changes in identified risks, the proposed improvements lead to a change in worker safety and health (Table 7):

Table 8 shows the improvements in the identified risks. The actions taken generate a change in the safety and health of workers.

Table 7. Safety gloves parameters

Parameter	Description
Environment	Dry and relatively clean
Brand	MAP
Serie	KRYNIT 563
Protection	Moderate and durability for difficult manipulations
Rule	EN 388, 4343, ISO 13997: 5.8 N, CAT2
Size	7–11
Length	22–27 cm
Interior finish	Seamless textile backing of HDPE fibers
Exterior finish	Nitrile on palm and fingers
Applications	Mechanical maintenance, mechanical sheet handling

Table 8. Current situation vs expected results

Identified risks	Current situation	Expected results
Order and cleanliness	Acceptable	Acceptable
Projection of fragments and particles	Not acceptable or acceptable with specific control	Acceptable
Hand entrapment	Not acceptable	Acceptable
Crushing hands	Not acceptable	Acceptable
Maintenance of machinery and facilities	Acceptable	Acceptable

4 Conclusions

This research work proposes risk management at the risk source, accident transmission medium and receptor (worker) in order to establish control measures and to ensure the safety of operators, reducing the risk levels of hand entrapment and crushing. In the oil and fuel filter cap manufacturing process on metal sheets. Forces and stress are present, and they must be considered so that they do not put the safety of the machine operators at risk. For hand-entrapment and crushing, risk levels were significantly monitored, from I (Not Acceptable) to III (Acceptable), because in both cases, the risk level deficiency was reduced from 6 to 2, i.e., some consequences may occur or that the effectiveness of the proposed set of measures is moderate. The level of risk exposure is still considered high since the worker is exposed to uninterrupted risk resulting in a risk probability level of 8 at which the situation is improbable, and the damage may ever occur. Furthermore, the consequence level decreased from 60 to 10 as injuries or illnesses may occur in the operator that do not require medical leave. In the case of the risk of projection of fragments and particles, a risk level II (Not Acceptable or Acceptable with specific control) was raised to a risk level of IV (Acceptable) since with the placement of the safety guard, the projection of pressed cap filter fragments will be prevented, so the efficiency of the proposed corrective measure is high, the risk is controlled and acceptable.

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Health and Working Conditions in the Prevention of the Risk of Professional Dropping-Out for Seniors: Results of a Statistical Survey

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Abstract. In a perspective of prevention of the risks of professional deintegration with the advancing age, the paper presents the results of the statistical exploitation of a French national survey on health and career paths. Among the factors associated with the risk of dropping out among the over 50s, these highlight the importance of employment paths, past exposure to work constraints and the duration of these exposures, and lastly, health-related factors. They also make it possible to characterize the socio-demographic and employment profiles of the individuals most vulnerable to the risk of dropping out. All of these elements call for the adoption of an integrative and combined approach to securing career paths, preserving health and improving working conditions.

Keywords: Ageing · Professional dropping out · Prevention

1 Introduction

In France, as in other European or Anglo-Saxon countries, the prevention of occupational reintegration, particularly among the over 50s, is at the heart of institutional priorities. It is driven by both employment and occupational health issues.

With the ageing of the population, the extension of the lifespan and the cost of financing pensions, keeping seniors in employment at an increasingly advanced age has become a major concern in a quest for financial balance of pension plans. Although the employment rate of seniors in France has risen sharply over the last 15 years [1], under the concomitant effects of pension and unemployment insurance reforms, the fact remains that older workers have difficulty staying in employment or returning to work.

At any age, health status plays a role in job retention and in the risk of exclusion from the labor market. Among older workers, impaired or weakened health can also result in premature exits from employment that can lead to permanent withdrawal from the labor market. Various French and European survey data show that the relative probability of

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being in employment decreases sharply after the age of 50 in the presence of health-related limitations [2]; and symmetrically, the risk of being unemployed or inactive is up to three times greater among seniors with health problems than among others [3]. This health status is not unrelated to working conditions. Certain constraints and work related strain leave significant, more or less immediate and sometimes long-lasting traces on health and work capacity. Atypical work schedules, demanding physical postures, repetitive work, frequent emergency situations, etc. put older workers in difficulty and contribute for some to their eviction from work. Physical hardship factors are not the only factors involved. The meaning of work, its interest, opportunities to develop new skills or to mobilize experience, to perform quality work, etc. are also particularly determining factors in job retention [4–6].

Deteriorating health status at the end of working life and exposure to deleterious work constraints can be vectors for job distancing. However, leaving employment at ages close to the end of working life can easily turn into a permanent cessation of activity [7]. As evidenced by unemployment insurance data, the average duration of unemployment for older workers is significantly longer than for younger workers, and the prospects for employment recovery are greatly reduced with increasing age [8]. As the duration of unemployment lengthens, older people's chances of returning to work diminish; their persistence in unemployment jeopardizes their chances of regaining a place in the labor market. However, when a return to employment does occur, it is often under deteriorated conditions, particularly in terms of qualifications or employment status.

Helping seniors to remain in employment, in a framework that is favourable to their health, implies, from a prevention perspective, a better understanding of the various factors associated with the risk of dropping out of the workforce at the end of one's working life. This is the objective of the following study, which sought to identify - notably through a statistical survey - the variables likely to predict dropping out by taking into account several professional and non-professional factors in an integrated manner. The results presented here question the roles of health, occupational wear and tear and past working conditions on the risks of dropping out of the workforce among seniors.

2 Method

The analysis presented here is based on a sample of employees aged 45 and over from the "Health and Career Paths" (SIP) survey. This French national survey was carried out among 11,000 people aged between 24 and 78 years old interviewed at 4-year intervals (2006 and 2010), regardless of their situation in the labor market. Its aim was to determine the interactions between life courses (personal, family, professional), exposures to occupational risks and working conditions, with the health of individuals. In addition to the prospective longitudinal approach, it also included a biographical retrospective approach carried out during the first interview.

Based on SIP survey variables, three categories of individuals aged 45 and over were considered, in different respects, to be in a situation of vocational dropout in 2010. The "downgraded" category includes employees employed in 2006 who, in 2010, held a job with a lower social classification or a less favorable type of employment contract than the previous one. Their situation is similar to a downgrading due to a downward employment path, job insecurity or the deterioration of their employment status between the two dates. The category of "likely dropouts" includes employees who were employed in 2006 and who, in 2010, are either long-term unemployed, or have been at home for at least one year, or have been inactive or out of work for health reasons for at least six months. Their situation in 2010 raises fears of a lasting loss of employment, which could lead them to drop out of the workforce. Dropping out seems likely, even if it is not proven: a return to employment is always a possibility. Finally, the "obvious dropouts" category includes employees who were employed at the first stage of the survey (2006) and who, in 2010, retired early for health reasons or after a long period (one year or more) of unemployment or inactivity without returning to work. Their retirement marks an abrupt end to their working life due to ill health, job loss or "voluntary" withdrawal from the professional sphere.

Of the 3116 workers aged 45 to 61 in 2006 - and reinterviewed in 2010 - 472 individuals meet the above-mentioned criteria for dropping out of the workforce. Several factors were taken into account in describing and analyzing the characteristics of these dropouts in 2006. Among the individual factors, sociodemographic characteristics, significant childhood events (including long illness, stressful living conditions) and significant adult life events were considered. Among the occupational factors, several aspects were analyzed: the characteristics of the job held in 2006; the stability, continuity and perception of the career path prior to 2006; and exposures to work constraints in the 10 years prior to 2006 (duration of exposure and intensity score). The working conditions concerned are night work, repetitive work, physically demanding work, exposure to harmful or toxic products, opportunities to use one's skills, work under pressure, tension with the public, recognition of the value of work, work-life balance, and social relationships at work. Finally, health characteristics in 2006 and before 2006 (perception of health status, number of health events and sick leaves of more than 6 months, limitations in usual activities for at least 6 months) and interactions between health and work path (disruptions in the path caused by health problems and health problems caused or aggravated by working conditions before 2006) were jointly taken into account in the analyses.

Each category of dropout was described in terms of individual characteristics, employment, working conditions, and health, before or in 2006, and then in pairs ("dropouts" versus "non-dropouts"). The probability of being a dropout in 2010, among those employed in 2006, was modelled by logistic regressions. In order to evaluate the relative weight of the different factors, each of them was introduced separately in a regression analysis. The association of dropping out with each factor cited was thus established, in the first instance, without adjustment for other factors; the factors were then considered simultaneously: only variables significantly associated with $p < 0.05$ were retained for successive testing by blocks of factors. The step-by-step regression method was chosen so as to retain only those variables that are most strongly related to the risk of dropping out. A predictive model of "dropping out" after the age of 45 was thus developed. The results of the logistic modelling are reported as the Odds Ratio (OR) of being a dropout versus being a non-dropout.

3 Results

Among the 3,116 subjects in the sample, there were 472 individuals in a drop-out situation in 2010, broken down as follows: 241 “downgraded”, 152 “likely dropouts”, and 79 “obvious dropouts”. The balance is made up of 2644 subjects referred to in the study as “stable”. Two types of results will be presented here: the characteristics of each category of individuals compared to each other, and the modelling of the probability of dropping out in 2010 adjusted for individual factors, past work factors, working conditions, health and work situation in 2006.

3.1 Characteristics of the Categories of Individuals

The “stable” ones. This group includes 1285 men and 1359 women. In 2006, it was divided equally among the 45–49, 50–54 and 55 + age groups. More qualified, they are also distinguished from the other categories by a career path composed mainly of long jobs (long jobs are jobs with the same employer for five years or more), and relatively few job changes and periods of unemployment. They are less dissatisfied with their career path than those who have been downgraded or dropped out, and fewer consider that their career path to have had a negative influence on their health, and vice versa. They also report better health.

The “downgraded”. This group consists of 103 men and 138 women. Their age structure is concentrated around the 45 to 49 age group (43%). The 50–54 age group accounts for 34% and the 55 + age group for 23%. Their employment path is more chaotic - both over the last ten years and over their entire career - than the “stable” ones; their position on the labor market until 2006 is also more precarious, with a higher proportion of employees on temporary employment contracts. Their health indicators are also lower. However, on all of these factors, the differences between “stable” and “downgraded” are less pronounced than they are between “downgraded” and the likely and obvious “dropouts” presented below.

The “likely dropouts”. Of this group of 152 individuals, both genders are roughly equally represented. More than 40% of them are between 50 and 54 years old. With the most individuals with few or no degrees (33%), compared to the “stable” ones, this category is mainly composed of unskilled employees and blue-collar workers, more than a third of whom work in maintenance and production activities in the industrial sector. For a quarter of them, the “likely dropouts” are precarious workers, living in households with incomes below the monetary poverty line (estimated at 60% of the median wage) compared to 15% among the “stable”. Their career path is characterized by greater job instability and higher proportions of periods of unemployment and short-term employment than for other categories: 45% of the “likely dropouts” have had at least two job changes in the last 10 years, compared with 29% of the “stable” group. They are also 3 times more numerous (11% against 4% for the “stable”) to have spent more than 10% of their working life unemployed. The likely dropouts have the highest levels of exposure to night work, physically demanding work, work under pressure and exposure to toxic or harmful products in the last 10 years. A larger proportion of them have also worked in jobs that were not properly recognized and in which their skills were not or only minimally used during the same period. In terms of health, the “likely dropouts" are 2.5 times more likely than the "stable" (27% versus 10%) to have reported at least 6 consecutive months of sick leave of in their professional career. They also consider, in higher proportions (15% versus 5%), that their health has disrupted their career path, and reciprocally that it has had an impact on their health.

The *"obvious dropouts"*. The majority of this group are women (50 versus 29 men). 72% of them were between 55 and 60 years of age. In many ways, their characteristics are similar to those of the "likely dropouts". However, a number of characteristics set them apart. Less precarious, they have longer jobs and fewer periods of unemployment. On the other hand, their career paths are significantly more unstable, in terms of the number of job changes over the course of their careers and over the past decade. The intensity of exposure to repetitive work is also greater among "obvious dropouts" than among other individuals; in 2006, almost a third of them worked in production in the industry. However, it is probably the aspects of health that differentiate them the most from the other categories: indeed, nearly 55% of them declare that their health is altered (compared to 45% for "likely dropouts" and 24% for "stable"). They are also 40% to have indicated significant limitations in their daily activities, compared to 24% of the "likely dropouts" and 12% of the "stable" group. Their higher average age is probably not unrelated to the higher proportion of reported health problems; however, it cannot be excluded that the hardship of past work experiences and working conditions may also explain this.

3.2 Statistical Modeling of the Risk of Dropping Out After Age 45

As previously mentioned, the probability of being in a dropout situation in 2010 was modelled by integrating, step by step, blocks of variables, and by retaining blocks of earlier variables only those significant at $p < 0.05$.

The first step was to integrate individual factors. Among these factors, the results show an effect of age, school level, family structure, and the number of significant events in childhood and adult life on dropping out. The risk of dropping out increases with age, especially in the 55–60 age group; it is greater among individuals without a diploma, living alone or in a single-parent family, and is increased with the increasing number of significant events in childhood and adult life.

In the second stage, past occupational factors were included. The results show an effect of the instability of employment in the last 10 years and the pourcentage of time spent unemployed during working life (more than 10%). Once these factors are taken into account, the number of events in adult life no longer has a direct effect on dropping out.

Exposures and their duration over the last ten years to the working conditions identified in the survey (for "always" or "often" exposures) were introduced in the third stage of the analysis. Once these working conditions were taken into account, the number of childhood events no longer had any effect. The likelihood of dropping out increases when individuals have been very frequently exposed in the last ten years to the following working conditions: physically demanding work, work not recognized for its fair value, tension with the public, the absence or low possibility of using one's skills, and work under pressure. The likelihood of dropping out also increases with the length of exposure over the last 10 years, for work that is not recognized for its fair value, lack of or limited opportunity to use one's skills, tension with the public, night work, and work under pressure.

The fourth step was to integrate health factors. The results show an effect of the number of sick leave of more than 6 months during the career and the perceived health status on the risk of dropping out. Once these factors were taken into account, as far as working conditions are concerned, only very frequent exposure to work under pressure and the duration of this exposure have an effect on dropping out.

Finally, in the fifth and final stage, factors relating to the working situation in 2006 were introduced: socio-professional categories, type of employment contract (long or short term), and professional sectors of activity.

The integration of all these factors in a multivariate logistic regression thus made it possible to determine the most predictive factors of a situation of professional dropout.

Among these, advancing age is a strong marker. The probability of dropping out in 2010 is a factor of 1.7 [1.1–2.68] for people aged between 50 and 54 in 2006 compared to those aged 45. It is multiplied by almost three times for those aged 55 to 60, for both men (OR = 5[2.52–9.97]) and women (OR = 4.9[2.68–8.84]).

Job changes over the last 10 years increase the risk of dropping out: even relative instability (with job changes on average at least every 7 years and at most every 3 years) increases the probability of dropping out by an OR equal to 1.6 [1.1–2.35]. There is also an important effect of the proportion of unemployment duration in the pathway on dropping out, starting at 10 percent unemployment in the career (OR = 1.9[0.99–3.7]).

Generally speaking, the socio-professional categories at risk of dropping out are mainly blue-collar workers (OR = 2.9 [1.35–6.27)) and employees (OR = 2.6[1.23–5.6]); The OR is of 3.5 [1.25–9.83] for male blue-collar workers. The sectors of activity in which the probability of dropping out is highest are the industrial sector (OR = 3 [1.64–5.68]), and the health and education sectors on the one hand, and the commercial sector on the other (OR = 2.5). From the point of view of working conditions, the duration of exposure to work under pressure proves to be a predictor of dropping out, with an OR = 1.05 per year (corresponding to an increased risk of dropping out by 63% after 10 years).

Finally, poor or bad health in 2006 is also a clear marker of dropping out 4 years later (OR = 2 [1.42–2.79]). But even more than the perceived health, the total number of sick leave of more than 6 consecutive months during working life predicts dropping out. The OR doubles when the number increases from one sick leave (OR = 1.7 [1.09–2.58]) to 2 or more (OR = 3.1 [1.52–6.31]). The effect is particularly strong for men (OR = 4.7[1.54–14.33]).

4 Discussion and Conclusion

Using SIP survey data on a population of individuals showing signs of dropping out in 2010, it was possible to access past characteristics of their personal, professional and health backgrounds and to establish links between these factors and the probability of dropping out. The factors associated with the risk of dropping out are multiple and concern both employment paths - and particularly its interruptions and discontinuities - as well as past exposure to penalizing work constraints, and finally the perceived health and known health events during working life. Other biographical factors, with lesser effects, also come into play, such as the number of significant events experienced during childhood. It is rather the professional and health aspects that we wish to focus on, in order to examine the conditions for the sustainability of pathways.

The results support the importance of career breaks in dropping out. These breaks are linked to employment, with frequent changes in work over the last 10 years, on the one hand, and the share of cumulative duration of unemployment in the career path, on the other. They are also related to health, with long sick leave during the career. There is evidence that the experience of unemployment and job insecurity produces a lasting feeling of vulnerability, which persists even when the employee returns to work. Employees who have experienced one or more spells of unemployment feel the pressures of their work more severely, and more than others the risk of unemployment in the future [10]. In terms of health, long stoppages are often the “antechamber” of a job exit whose return to work is uncertain: the probability of returning to work decreases as the duration of the sick leaves [11]. It is interesting to note that in our study, the risk of dropping out at 4 years increases sharply with the increase in the number of long-term sick leaves, regardless of the point in the career when they take place. Long breaks from employment and work - its context and environment - affect individuals in such a way as to make them visibly even more vulnerable to other hardships in their working lives.

The results also tend to show the effects of working conditions and duration of exposure on the risk of dropping out. The working conditions concerned are not only physical constraints but also psychosocial constraints, some of which are linked to the lack of recognition of the value of work and the skills of individuals. Among these working conditions, work under pressure is the one most strongly associated with the risk of dropping out. We know how difficult it is for aging employees to cope with sustained rhythms or tight deadlines. [12] However, working under pressure refers to numerous realities: rhythms imposed by production standards, by the automatic speed of a machine, by customer or public demand, but also pressure from the hierarchy. The statistical survey has its limits here in order to better define the contours of “work under pressure”. On the other hand, this will be possible within the framework of qualitative analyses which will be carried out with individuals over 45 years away from employment for more than one year. These analyzes, based on biographical interviews, will make it possible to account for the gradual process of dropping out, and the dynamics that lead to it. By drawing up the characteristics of the individuals most at risk of dropping out, of which the category of “likely dropouts” is the most representative, we highlight the different facets of dropping out that we must pay attention to from a prevention perspective. These different elements of analysis provide valuable indications, particularly to institutional preventers and health services, to guide their prospective approach and target their actions, particularly among low-skilled workers and employees in the industrial, commercial, and health sectors, who are most at risk of dropping out.

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Performance Implications of Safety Training

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Abstract. Safety management practices aim to improve working conditions and safety performance. Safety training can positively affect employees' safety knowledge, safety motivation, safety compliance and safety participation, which are the main factors of safety performance. Several models for evaluating safety training effectiveness have been suggested. The aim of this paper is to study how employees' safety performance can improve after safety training intervention. The effects on safety performance were studied in two units of a case company based on a questionnaire and selected indicators. A descriptive analysis was performed with the data gathered. Based on the survey (n = 45), some improvements in safety knowledge, attitudes, behavior and safety performance can be found. Indicator data also show a positive trend during the studied period. The amount of preventive actions has increased, and the number of injuries has decreased. This study contributes to the current knowledge on evaluating the performance implications of safety training.

Keywords: Occupational safety and health · Safety training · Safety performance · Performance measurement

1 Introduction

Safety management practices aim to improve working conditions at the workplace and positively influence employees' attitudes and behaviors with regards to safety, thereby improving safety performance [1]. Safety performance is typically defined as actions and behaviors adopted to promote health and safety or to reduce safety events, such as accidents, at work [2–4]. Safety training interventions are one of the most important safety management practices. Safety training can positively affect employees' safety knowledge, safety motivation, safety compliance and safety participation, which are commonly considered the main factors of safety performance [1, 5–7]. Moreover, appropriate safety training may improve safety culture [8]. However, the training outcomes may be reduced over time [9]. Evaluation of safety training effectiveness is crucial to deliver continuous and adequate training to improve safety performance [9–11].

Safety performance is typically measured by both lagging and leading indicators, and their use should be balanced [4, 12–15]. Lagging indicators typically include the number or frequency of occupational fatalities, injuries and illnesses. Lagging indicators typically include the number of preventative measures carried out to improve safety, such as safety walks, discussions or audits and related corrective actions.

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Several models for evaluating safety training effectiveness have been suggested [9–11, 16]. These models typically address safety knowledge, safety attitudes and beliefs, safety behavior and health. In our previous study [16], a model and related questionnaire was designed for this purpose. The model was evaluated and determined to be suitable for its purpose, as it is comprehensive and compiles the major objectives for effective safety training and reveals differences between different perspectives on safety performance [16]. However, there is still a need to apply and empirically test the instruments designed for evaluating the performance implications of safety training. This study provides more specific understanding on how training affects the different elements of safety performance.

Safety performance indicators could be better utilized in evaluating the effectiveness of safety training [16]. Studies combining different forms of measurement information (e.g. questionnaire and safety statistics) in the analysis are needed to gain more comprehensive knowledge on the performance implications of safety training [9, 16]. The aim of this paper is to study how employees' safety performance can improve during a six-month period after a safety training intervention in two units of the case company. The effects on safety performance were studied based on a questionnaire and selected leading and lagging indicators.

2 Materials and Methods

The safety training was carried in two units (unit 1 and unit 2) of a large company providing support services for facilities management. It consisted of participatory classroom lessons, with practical examples and discussions moderated by an expert. The training aimed to change employees' behavior and support the development of safety culture. The whole work team, including the supervisors, participated in one training session of four hours. The training sessions were arranged during November and December 2019, and the total number of participants was 300.

The effects on safety performance were studied based on a questionnaire [16] and selected indicators for safety performance. The questionnaire was carried out during February 2020 (two to four months after the training sessions). It consisted of 48 questions (43 Likert-scaled questions and 5 open questions). Forty-five responses from two units were received, 51% from unit 1 and 49% from unit 2. Most of the respondents were males (93%) and had more than one year of work experience in the company in question (96%). Three of the respondents (7%) were supervisors, and 42 (93%) were employees. The respondents evaluated the effects of the safety training with relation to the four themes: 1) safety knowledge, 2) safety attitudes, beliefs and motivation, 3) safety behavior and 4) safety performance [16].

Safety performance indicator data (leading and lagging indicators) were gathered before and six months after the training to complement the survey data. Leading indicators included the number of preventive actions taken, namely, safety observations, safety walks, safety moments, workplace risk assessments and machine risk assessments. Lagging indicators included the number of lost time accidents (LTA) and total recordable injuries (TRI). Descriptive analysis of the gathered data was carried out, and the performance implications of safety training were evaluated. The results and performance implications of the training intervention were reviewed with the company safety representative to interpret the results.

3 Results

Based on the questionnaire, most of the respondents (73%) agreed that safety training has positive effects on occupational safety by decreasing the number of occupational injuries (mean 3.78). Similarly, most of the respondents (68%) agreed that the training improves the workplace climate (mean 3.75). The respondents stated that the training caused them to better plan work and observe risks before starting the job, become more aware of the consequences of an occupational injury and understand the wider picture. The summary of the results is shown in Table 1.

Table 1. Summary of the survey results (n = 45).

Perspective	Sections	No. of questions	Mean
Safety knowledge	Working environment Ability to work safely	4 4	3.66 3.74
Safety attitude, beliefs and motivation	Understanding the significance of safety Risk perception Safety motivation	5 4 3	3.80 3.72 3.95
Safety behavior	Adhesion to the instructions Feedback Active safety participation	4 3 5	3.62 3.39 3.52
Safety performance	Effects on occupational injuries Effects on workplace climate Supervisory performance Employee performance	1 1 4 5	3.78 3.75 3.76 3.81

1 = disagree, 2 = partly disagree, 3 = neither agree nor disagree, 4 = partly agree, 5 = agree

Most of the respondents (70%) felt that the training improved their *safety knowledge* and ability to work safely in different kind of situations (mean 3.70), for example, to observe the working environment and acknowledge hazards. Most of the respondents (67%) perceived that the training had positive effects on their *safety attitude*, *beliefs and motivation* (mean 3.81). Interestingly, the training seemed to have the greatest effect on the employees' safety motivation (mean 3.95), such as striving for a high level of safety, working safely and caring for each other. The respondents perceived that after the training safety issues are discussed more often and safety problems are tackled more actively.

The training also had some positive effects on *safety behavior* (mean 3.52). About half of the respondents (53%) agreed that after the training they more actively follow safety instructions, get and give safety feedback and participate in safety development. It is noteworthy that there is room for development, especially in giving positive feedback about working safely and paying attention to physical ergonomics. Most of the respondents (69%) perceived the safety climate as quite positive (mean 3.79). For example, the majority of the respondents stated that they take their fellow workers' safety suggestions seriously (mean 3.88) and can discuss safety matters openly (mean 4.14). Moreover, they reported that supervisors ensure that every employee can influence his or her own occupational safety (mean 3.91) and encourage employees to always follow the safety instructions (mean 3.77).

There were some differences between the results of the two units. In unit 1, the effects of the training were perceived as overall more positive than in unit 2 (approximately 0.1–0.6% difference per question). However, supervisor performance was evaluated the same or slightly more positive in unit 2 (0.2–0.3% difference in two question). Employee performance was perceived more positively in unit 1 than in unit 2 (0.1–0.4% difference per question).

The safety performance indicator data were gathered during six months after the training (January 2020 – June 2020), and a five-month moving average was calculated (Fig. 1 and Fig. 2). The number of preventive actions taken slightly increased during the period in the whole data set and in both units, especially safety walks, workplace risk assessment and safety observations. The LTA rate decreased in the whole data set and in both units (30% in unit 1 and 27% in unit 2). The TRI rate decreased in the whole data set but decreased by 30% in unit 1 and increased by 25% in unit 2.

Fig. 1. Five-month moving average of monthly preventive actions taken (number).

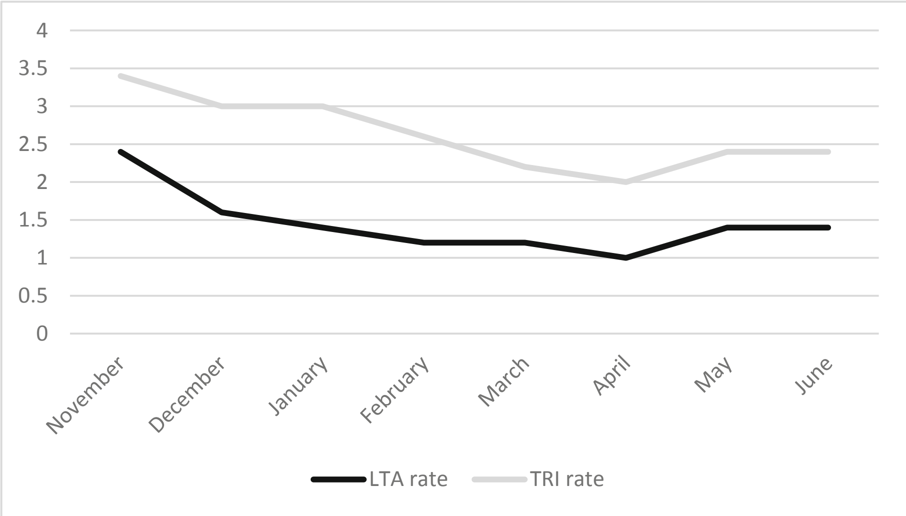

Fig. 2. Five-month moving average of Lost Time Accident (LTA) rate and Total Recordable Injury (TRI) rate (number).

Based on the review by the company representative, the participants evaluated the quality of the training positively. Some effects on safety knowledge, attitudes, beliefs and motivation were perceived after the training, but they were not expected to have an immediate effect on safety behavior or safety performance.

4 Discussion

Based on the survey results, some improvements in safety knowledge, attitudes, behavior and safety performance can be found. The results reinforced the view that training will not affect safety behavior instantly [9, 11]. However, some direct effects can be found, for example, with regard to following the safety instructions. Nevertheless, safety training remains inadequate if it does not support behavioral changes [9, 16].

Indicator data also show a positive trend in safety performance during the studied period. The amount of preventive actions has considerably increased while the number of injuries has decreased. More active reporting of and participation in safety issues may indicate behavioral changes after the training. The safety performance indicator data indicated even more positive development than the company representative expected.

The safety performance indicator data are not fully comparable between 2019 and 2020 due the exceptional COVID-19 epidemic situation during 2020. The employees of the company in question typically cannot do remote work since they carry out facility services at customer premises. Hence, the focus of safety work has been on sheltering from coronavirus and preventing it from spreading in the workplace during spring 2020. To manage this challenge, a moving average was used to smoothen the data and decrease the impact of random, uncontrollable factors. However, the indicator data should be followed for a longer period to confirm the effects. In the future, a second survey round could be carried out to study the permanence of the effects.

Most of the respondents were employees, and hence the survey results may be biased toward more positive evaluation of employee performance than supervisory performance. It is noteworthy that the dispersion of supervisory performance was relatively high. This indicates differences between the supervisors, for example, in how they encourage employees to work safely. Moreover, the differences in indicator data between the units may also indicate differences between the supervisors.

There were some differences in the survey results between the two units. In unit 1, safety training was perceived more positively than in unit 2, even though both units perceived the training as advantageous. The safety performance indicator level was significantly better in unit 1 than in unit 2. In unit 1, the respondents were more critical of the supervision. This may indicate differences in supervision, willingness to accept training or how well the training meets the current situation in the unit. Thus, the same kind of training might not be suitable for every unit, and the training should be tailored based on the participants' needs.

This study contributes to the current knowledge on evaluating the performance implications of safety training. Specifically, it advances the understanding of how safety training creates benefits. The results of the study can be utilized in planning adequate interventions and related measurements to improve safety. In addition, the study presents an approach for evaluating the impacts of safety training, which may be followed in other case contexts. This approach can be seen as a tool for safety managers in recurring analyses of safety-related training.

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Absenteeism, Musculoskeletal Disorders and Healthy Living Habits in Active Uniformed National Police

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Abstract. To characterize cases of absenteeism and the healthy lifestyle habits of the uniformed population of the Santiago de Cali-Colombia region. Absenteeism records for the year 2019 were unified together with reports of physical condition of the uniformed population, with a history of this circumstance, to apply the frequency distribution. 80% of the cases corresponded to a population in the age range of 26 to 40 years, most of the medical diagnoses presented affection of the musculoskeletal system, where the trunk and lower limbs appeared the as the most compromised segments. 24% presented some degree of overweight or obesity, linked to the most frequently affected body areas. The literature reports the influence of sedentary lifestyle in the appearance of musculoskeletal disorders affecting the absenteeism, so the development of studies with an analytical scope and the consideration of health promotion in the workplace by the organization under study becomes important.

Keywords: Police · Absenteeism · Sedentary behavior · Healthy lifestyle · Musculoskeletal pain

1 Introduction

The World Health Organization (WHO) defines absenteeism as a phenomenon of absence due to direct or indirect avoidable causes such as illness, whatever its duration and character may be, as well as unjustified absences during all the working day or part of it, as well as the circumstantial permission within working hours [1]. All organization with a public or private nature presents this problem, even entities of a special nature such as the police.

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Studies characterizing the causes of absenteeism in police officers have found sleep disturbances with high frequency, as well as cases of depression, diabetes, and cardiovascular diseases [1], the latter being associated with irregular healthy lifestyle habits [2].

Additionally, inappropriate healthy lifestyles have also been linked to the generation of musculoskeletal disorders in these population. For example, the relationship between anthropometric measures such as body mass index (BMI) with alterations in the lumbar region, or cases of carpal tunnel syndrome has been studied [3, 4].

Based on the above, this research presents the characterization of cases of absenteeism and healthy life habits of the uniformed population attached to the Metropolitan Police of Santiago de Cali-Colombia. This is because a significant percentage of uniformed personnel have been identified as repeatedly absence during 2019 due to musculoskeletal alterations.

For this institution the analysis of absenteeism presented in the unit is important due to the possibility of a decrease in the work capacity of its collaborating population, since this leads to rehabilitation process and absences from the service generating work overload in the other uniformed group of people and, if this is not controlled, it may increase the complexity of the health problems, the administrative processes, and the costs for the entity.

2 Materials and Methods

The study is proposed with a quantitative approach and descriptive scope, by characterizing the absenteeism in this group population and the aspects associated to the physical condition of the uniformed population.

For this, the absenteeism records of the uniformed population of the Santiago de Cali-Colombia unit in 2019 where considered, between the months of January to October and a database with physical tests carried out on the population of this unit were considered, coinciding those with this background. The information from both databases was consolidated or unified and it was processed through Excel to apply frequency distribution.

For the development of the study, we had the authorization of the entity to dispose of the information and its processing, guaranteeing the respective confidentiality and reservation of this, as well as the approval of the research ethics committee of the Corporación Universitaria Minuto de Dios - UNIMINUTO, campus Bogota (Colombia).

3 Results

In the period described above, a total of 1802 cases of absenteeism were found in the unit. 87% of the cases were of male uniformed, almost 80% of the events occurred in the population in the age range of 26 to 40 years. Most of the reports of absenteeism were presented among the low-ranking uniformed population. (See Table 1).

Table 1. Demographic characterization of the population with a history of absenteeism from the Santiago de Cali unit. 2019.

Variable		N number	% percentage
Sex	Female	232	13
	Male	1570	87
Age range	19 a 25 years	109	6
	26 a 30 years	435	24,1
	31 a 35 years	478	26,5
	36 a 40 years	523	29
	41 a 45 years	202	11,2
	46 years in advance	55	3.1
Degree	Auxiliaries, agents, and executive level	1772	91,4
	Official level	19	1
	Non-uniformed personnel	11	0,6

Source: the authors.

Regarding the characterization of the absenteeism cases, almost all the events affected the musculoskeletal system and in 53.4% the part of the body most affected was the trunk, followed by the lower limbs with 33.2%. In relation to the physical condition of the uniformed men, it stands out within the anthropometric measures, that 17% presented some degree of overweight and 7% some degree of obesity. (See Table 2).

Table 2. Description of the system and part of the body affected by the reported absenteeism and physical condition of the uniformed population of the Santiago de Cali unit. 2019

Variable		N number	% percentage
System affected	Osteomuscular	1792	99,4
	Immune system	9	0,5
	Nervous system	1	0,1
Body part affected	Upper limbs	7	0,4
	Lower limbs	599	33,2
	Neck	4	0,2
	Trunk	963	53,4
	Whole body	3	0,2
	No specific data	226	12,5
Body mass index	Malnutrition	2	0,1
	Obesity Grade I	70	3,6
	Obesity Grade II	17	0,9
	Obesity Grade III	50	2,6
	Overweight Grade I	106	5,5
	Overweight Grade II	221	11,4
	No specific data	1336	68,9

Source: the authors.

When crossing the absenteeism data according to the part of the body affected with the BMI classification, it is found that 5.2% of the cases whose affected area was the trunk, the population was overweight grade I, and 14% overweight grade II. 6.8% of the cases where the affected area was the lower limbs, the population was grade I overweight and 8% were grade II overweight. (See Table 3).

Table 3. Contingency table. Affected body part and classification of the body mass index of the uniformed population of the Santiago de Cali unit. 2019

		Affected body part						Total
		Upper limb	Lower limb	Neck	Trunk	Whole body	No specific data	
Rank BMI classification	Malnutrition	0	0	0	2	0	0	**2**
	Obesity grade I	5	20	0	32	0	13	**70**
	Obesity grade II	0	0	0	13	0	4	**17**
	Obesity grade III	0	21	0	26	0	3	**50**
	Overweight grade I	0	41	0	50	0	15	**106**
	Grade II overweight	0	47	0	134	0	40	**221**
	Does not apply	2	470	4	706	3	151	**1336**
Total		**7**	**599**	**4**	**963**	**3**	**226**	**1802**

Source: authors.

4 Discussion

As mentioned above, a proportion of absenteeism cases occurred in the 26 to 40 age group, a population that is in the full productive stage. This element is an aspect to be reviewed by the institution, given the consequences it may bring and due to the characteristics of the entity's mission, related to public safety. Melo et al. [5] found a significant relationship between the health conditions of military personnel, linked to the effects of stress and age ($p = 0.018$), which may affect the indicators of absenteeism.

It was found that in most cases of absenteeism, the most affected body system was the musculoskeletal system. The most frequently presented diagnoses were: Cervicalgias, back pain, among others, showing that the body area most affected was the trunk. Based on the above, it is important to carry out a thorough analysis of the risk factors present in the activities or functions. Medina et al. [6] carried out a study aimed at analyzing the workload in the surveillance group of the Tunja station - Colombia, showing that 91% of the respondents considered that the functions request a level of physical demand between high and very high, and 95% indicated that the cognitive demands requested by the task are between high and very high. Additionally, statistically significant relationships were demonstrated between the perception of the level of cognitive demands requested by the tasks, and the level of academic training ($p < 0.05$).

In relation to the intersection of variables "part of the body affected" and the "BMI" of the population with a history of absenteeism, it was found a proportion of cases whose compromised area was the trunk and presented some degree of overweight or obesity, which may be related to physical activity habits. Given this, it is important to continue investigating the possible relationship of these aspects based on the association that studies have shown [7]. Hruby et al. [8] found in their research a tendency to increase the cases of overweight and obesity among the military. Kirsch et al. [9] determined as a protective factor the habit of doing physical activity to prevent discomfort in the lumbar area (RR: 0.83, CI: 0.75–0.93).

Reviewing the absenteeism records of the Santiago de Cali unit from January to October 2019, a considerable proportion of cases of uniformed persons was found in the age group between 26 and 40 years, being the most affected system the osteomuscular one, as well as the the trunk and lower limbs. Within the physical tests of the population with a history of absenteeism, personnel with some degree of overweight and obesity were found whose affected area was the trunk. According to the scientific literature, this condition can be associated with a predisposition for musculoskeletal disorders, which is why it is important to develop studies with an analytical scope that allow evidence of this associations. In addition, to review policies on health promotion at the workplace is also very important with this specific population.

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Safety Perception and Safety Culture

Safety Culture and Risk Perception in a Furniture Manufacturing Company – A Case Study

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Abstract. Workers in furniture manufacturing are often exposed to various types of risks. This paper results from a study carried out in a large furniture manufacturer operating in Portugal. The main goals were the evaluation of the workers' risk perception and safety culture. In this exploratory research, the William Fine risk assessment method was applied across 2 production section lines (with a total of 103 workers) by safety experts. Subsequently, several meetings occurred, whereby, the results of risk assessment were shared with the workers. Simultaneously, these workers were requested to answer a questionnaire designed to evaluate their risk perception and safety culture. Globally, the results demonstrated a positive relationship between workers' perceptions and the experts' assessments. Furthermore, this research concludes that there is an increasing awareness of workers and a move towards a positive safety culture that could facilitate an open and resilient approach to all safety practices.

Keywords: Risk perception · Safety culture · Furniture industry · Safety procedures · Risk assessment

1 Introduction

Manufacturing industries report a significant number of occupational accidents. Workers in furniture manufacturing are often exposed to hazards such as dust, chemicals, noise, tool vibration, hazardous machinery, vehicle traffic, fires and explosions [1]. Additionally, higher physical demands, such as repetitive movements, awkward postures, and manual forces exertion, are very common for workers in the manufacturing industries [2]. An understanding of the role of human factors and safety culture has become an important issue for this sector. Currently, the safety culture relevancy and, with it, the importance of the communication between employers and workers as well as the active participation of the workers in the management of their own safety, is well established and the new ISO 45001 is a strong evidence of that. According to a study of literature review about safety culture, many organizations around the world are showing increasing

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interest in the concept of safety culture as a means of reducing the potential for disasters, accidents, incidents or near misses within their everyday tasks [3]. The authors of the referred study consider that safety rules should be understood and adhered to by everyone, as well as all incidents must be reported and investigated quickly for actions to be taken, and for increased learning. In order to achieve a positive level of safety culture into an organization, a holistic approach is recommended, which strengthens the concerns with company performance jointly with safety and well-being for the workers [4].

According to Tear *et al.* [5], only through examining how national cultural contexts influence the power dynamics of an organization that a full understanding of organizational culture can be understood. National culture appears to differentially affect different organizational roles, with controllers being the most affected, managers and administrative staff similarly affected, and engineers unaffected.

It is important to know the employees' perceptions. For example, experiment managers often recognize that an employee's perceptions are highly predictive of his/her behavior in a given situation, such as compliance with safety rules or standard safety practices [6]. The same author suggests that when management's commitment to safety is clearly demonstrated through action, employees' perceptions of the safety management process are positively influenced. Along with that change in perception, it seems that there is a strong causal relationship with a reduction of injury rates.

The main goals of this study consisted of the evaluation of the risk perception of the workers and also the safety culture. It was also intended to compare the workers' risk perceptions with the risk analysis made by experts.

2 Methodology

This work results from a study carried out in a large furniture manufacturer operating in Portugal, where most of the work accidents and incidents are related to human errors/unsafe acts.

In this exploratory research, William Fine risk assessment was implemented across two production sections (with a total of 103 workers divided into 3 shifts) by 4 safety experts. One of these sections, hereinafter named Assembly Production Section, is composed of 14 workstations of manual assembly. The other section (Packing Production Section) describes the production in line with the final packing of furniture pieces. In both sections manual and repetitive tasks are commonly performed.

The workers of these sections shared with the evaluators their perceptions regarding working conditions, complaints and suggestions for improvement.

Visits were carried out in order to collect individual data from each workplace, information on work organization, physical and mental requirements, eventual workers' complaints/injuries, working conditions, tasks performed, dangerous conditions, occupational risks identified, and preventive measures implemented. Photographs and videos of the workers performing their tasks were also registered.

The identification of the risks for each workplace was carried out by direct observation of the workers during the normal execution of their tasks. During the visits to the workplaces, other relevant data were also collected to fill out a matrix (for each workplace), which includes William Fine's matrix for the calculation of the risk degree. The risk assessment was based on the William Fine method, which is based on equations expressing control of hazards and the rationale for investments in deciding on preventive measures. It attributes a degree of risk that is calculated on the basis of three factors, each one rated by diverse scores depending on the different classification:

(i) the probability of the accident occurring (Class = score: Most likely = 10; Quite possible = 6; Unusual = 3; Remotely possible = 1; Extremely remote = 0.5 and; Practically impossible = 0.1);
(ii) the degree of exposure to risk (Class = score: Continuously = 10; Frequently = 6; Occasionally = 3; Unusually = 2; Rarely = 1and; Very rarely = 0.5);
(iii) the consequences of the accident (Class = score: Catastrophic = 100; Critical = 50; Major = 25; Moderate = 15; Minor = 5 and; Negligible = 1) [7].

Given the classifications for each of these factors, the Risk Score (RS) could be determined using Eq. 1

$$R_S = F_P \times F_E \times F_C \tag{1}$$

Where FP is the probability factor, FE is the exposure factor and FC is the consequence factor.

The RS (or risk level), whose classification is presented in Table 1, allows the establishment of a prioritization of the actions to be performed. Subsequently, several meetings occurred, whereby, the results of risk assessment were shared with the workers. Simultaneously, these workers were asked to answer a safety culture questionnaire, designed to evaluate their risk perception and safety culture. In this study, 75 workers of the Assembly production line and 28 of the Packing production line participated and answered to the questionnaire. The questions were divided into the following four categories:

(i) demographic data, such as gender, age, work experience, allowing the sample characterization;
(ii) communication and workers' participation in safety/preventive measures;
(iii) training and information about safety procedures;
(iv) perceptions about the risks.

In the second, third and fourth categories, the questionnaire included a set of statements that the workers have to classify using a 5-Likert scale. The Likert scale originally introduced by Rensis Likert in 1932 is the most widely used psychometric scale in opinion polls [8]. In this case, workers are requested to indicate their level of agreement with each particular statement. The 5-Likert scale is labeled as follows: 1 = Never; 2 = Sometimes; 3 = Usually; 4 = Often; 5 = Always.

The statements about the second and third categories were based on the guidelines of the European Agency for Safety and Health at Work [9]. In the last category, the workers reported their perceptions about the frequency of the exposure to the different risks assessed by William Fine method.

Table 1. Classification of risk level.

Risk level	Risk score	Priority
I	≥250	Immediate correction required; activity should be stopped until the hazard is reduced
II	90 to 250	Urgent! Requires attention as soon as possible
III	18 to 90	Hazard should be eliminated without delay, but the situation is not of an emergency
IV	≤18	Should be addressed when time is given

3 Results

3.1 Communication and Participation

As mentioned above, a questionnaire was applied in order to collect the workers' perceptions about communication and participation in their workplaces. The results (Fig. 1) show there is positive communication and worker participation in the two production sections.

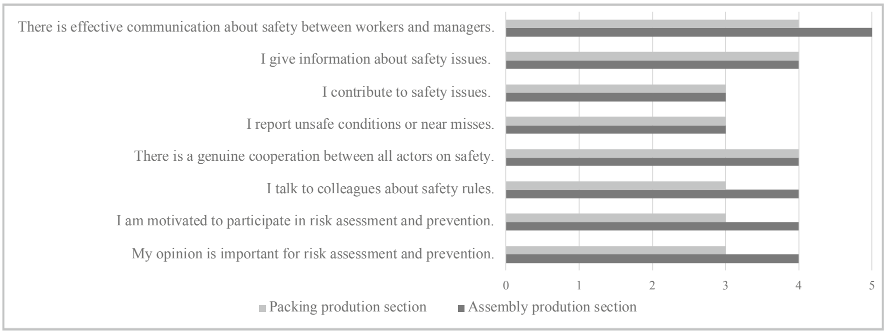

Fig. 1. Communication and participation of a packing (n = 28) and assembly (n = 75) production sections. The classification of answers was: "1 = Never"; "2 = Sometimes"; "3 = Usually"; "4 = Often"; and "5 = Always".

In the packing production section, the workers answers 'often' for the statements regarding the communication about safety, giving information about safety issues, and cooperation between all actors on safety. They answer 'usually' for the remain statements. In the assembly production section, workers thought there is 'always' an effective communication about safety. They also answer 'usually' for the statements regarding their opinion about information on safety issues and reporting unsafe conditions or near misses. They answer 'often' for the other statements.

3.2 Training and Safety Procedures Information

Regarding the workers' perception of training and information about safety procedures, it was also assessed by answering a questionnaire. Figure 2 shows positive results for both production sections. In the packing production section, the workers scored, in median, all statements as 'often'. In the other production section, the score given by the workers for almost every statement was 'always', except for confidence about having the safety training needed, which was scored as 'often'.

Fig. 2. Training and safety procedures of a packing (n = 28) and assembly (n = 75) production. The classification of answers was: "1 = Never"; "2 = Sometimes"; "3 = Usually"; "4 = Often"; and "5 = Always".

3.3 Risk Assessment and Risk Perception

In order to compare the risk assessment with the workers' perception of the risk they are exposed to, the William Fine method and a questionnaire were applied, respectively. The classification of the risks were: a. Noise; b. Chemical contaminants; c. Temperature variations; d. Particles/Dust; e. Poor lighting; f. Fall to the same level/fall in height; g. Clash with/against objects or machines or people; h. Disrespect for ergonomic principles; i. Fire risk; j. Electrical hazards; k. Contact with fluids/surfaces at high temperatures; l. Contact with sharp elements; m. Contact with moving machine elements; n. Psychosocial risks; o. Projection of particles/objects/materials; p. Compressed air projection; q. Vehicle traffic.

Figure 3a shows the results of the packing production section. Globally, the evaluators and the workers identify the same risks, although the risk level assigned by the evaluators are higher than the risk identified by the workers.

The results for the exposure comparison between risk assessment and workers' risk perception of the assembly production section are shown in Fig. 3b. In this production section, the evaluators and the workers identified the risks of noise, disrespect for ergonomic principles, contact with fluids/surface at high temperatures and, contact with sharp elements with the same risk level. The other risks were assessed with a higher risk given by the evaluators or vice versa. There are also some risks identified by the workers that the evaluator didn't take into account.

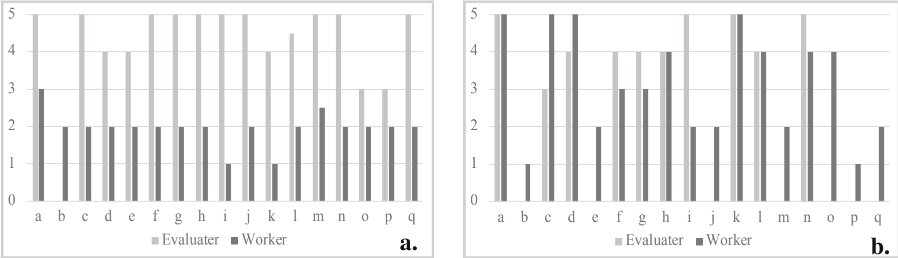

Fig. 3. Exposure comparison between risk assessment (n = 4) and workers' risk perception *(a)* of the packing production section (n = 28); *(b)* of the assembly production section (n = 75).

4 Discussion

Safety culture has been identified as a critical factor that sets the tone for the importance of safety within an organization [6]. With this in mind, we proposed to evaluate the safety culture of two production lines using a questionnaire to conclude about communication/participation of workers, training and safety information and perception of exposure to occupational risks (compared with the evaluator's assessment using the William Fine method).

Regarding communication/participation of workers, in the packing production section, it is better the communication between workers and management, giving information about safety issues and the cooperation between all actors on safety. In the other production line, the results are very positive for the most options, notwithstanding the workers' perception about the contribution to safety issues and reporting unsafe conditions or near misses were less scored. These results reveal that both production sections are sensitive to this thematic, however, the assembly production section is slightly highlighted. This may indicate greater information sharing between workers and team leaders. It also seems that the workers of this production section are more motivated and interventive in safety issues related to their jobs. These results show that is necessary to improve communication between the stakeholders in the packing section.

Concerning the training/information on safe procedures, it appears that the assembly production line is again highlighted, albeit slightly. This may again indicate that information is reaching workers more effectively in this section. In the packing section, the transmission of information should be improved, as well as investing in workers' training.

The exposure perception to conditions considered dangerous or potentially causing injuries is not constant, once it varies with both the individual and the context [10]. Figure 3a confirms this, once the opinions of the evaluators and workers do not show the same results. The evaluators' understanding presupposes greater exposure to the identified risks. However, there is a risk (exposure to chemical contaminants) that workers identified as being exposed, that the evaluators did not consider.

It should be noted that the evaluations were performed workstation by workstation, in a single moment. For that reason, this evaluation may not contemplate the different work shifts and the different production processes, as well as the different seasons. Consequently, and concerning Fig. 3b, workers in this section may have identified risk exposure that was not identified by the evaluators. In this production section, there are different opinions between evaluators and workers. The evaluators consider that there is greater exposure to the risks of falling at the same level or falling in height, clashing with/against objects or machines or people, fire, and psychosocial. However, workers perceived to be more exposed to the risks of temperature variations and particles /dust than evaluators. It is also shown that workers consider themselves to be exposed to risks that evaluators did not consider exposure to exists (e.g. poor lighting or electrical hazards). In this way, and although the worker being asked about the different tasks of his job, some risks may not have been considered because they did not occur at the time of the assessment. The fact that the risk assessment contemplates only a specific time of year may have led to different opinions between evaluators and workers, regarding the risk of exposure to temperature variations. This divergence also extends to the risk of exposure to particles/dust in which the daily and/or weekly maintenance of the assembly production section was not observed.

The different results may suggest that, even slightly, the safety culture can be more intrinsic in the assembly production section, which may influence positively the adoption of safe behaviors, to prevent accidents at work. In a study [11] addressing the link between perceived risk and behavior among 516 workers from eight different companies, has been showed that the more positively workers viewed the safety climate the more they reported wearing protective hearing gear.

Overall, the results of this study point out that the assembly production line, where there is a greater perception of risk, is also the one where there are better communication and participation and better knowledge about training and safety procedures. This suggests a link between risk perception and the existence of a better intrinsic safety culture. This will make it possible to reduce the occurrence of work accidents, since previous studies demonstrate that the better the safety culture, the lower the injury and illness rates are likely to be [12].

5 Conclusions

In the past decades, safety climate has been recognized as a fundamental and ultimate solution for improving workplace safety in various industries. In order to improve safety performance of a company, it is necessary to focus on the human aspect. This work made it possible to recognize which areas, in the selected production lines, related to the safety culture should be improved. This work also made it possible to verify a relationship between the perception of risk and the existence of a more intrinsic safety culture in one of the production lines in relation to the other. This work will serve as a pilot study that will allow to be applied to the other productive lines of the manufacturing furniture industry under study in order to assess the safety culture and risk perception of the workers. Furthermore, this research concluded that there is an increasing awareness of workers and a move towards a positive safety culture that could facilitate an open and resilient approach to all safety practices.

As future work, it is intended to relate the safety culture and the perception of risk with the reports of work-related accidents in each of the production lines under study and others in order to increase the sample.

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Post COVID-19 Fatigue Management for ATCOs

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Abstract. In the context of the outbreak of COVID19 and its effect on the aviation industry, air traffic controllers (ATCOs) have seen both their working and living conditions significantly affected. These effects may increase the risk of fatigue, especially when traffic increases again, with potential consequences for flight safety and the ATCOs' health and well-being. This paper reviews the main risk factors of the pandemic on ATCO fatigue and proposes some recommendations to manage this risk.

Keywords: Air traffic control · Shift-work · COVID19 · Fatigue · Fatigue risk management system

1 Introduction

The aviation industry is one of the industries worst affected by the outbreak of COVID-19. There are uncertainties regarding its duration and impact, but the impact is already massive. Air traffic restrictions imposed on the population and the closure of borders have disrupted the usual flow of travellers. In addition to the dramatic reduction in air traffic, this crisis has created a large area of uncertainty. In the most optimistic scenario, the forecast has traffic returning to 2019 levels by 2024. However, in a second scenario (based on vaccine availability and efficiency), traffic in 2024 would only be 92% of the 2019 level. In a third scenario, traffic in 2024 would be 75% of the 2019 level and would not reach the level seen in 2019 until 2029.

In this context, the crisis is having a huge impact on air traffic controllers' (ATCOs') professional and private lives, with many of them working fewer hours because of the drastic reduction in the number of flights. The main challenge in the medium term for air navigation service providers (ANSPs) is to resolve staffing problems and ensure flexible use of staff in order to enable optimum sector configurations to be opened when needed. This calls for robust staff planning and for the recruitment and training of additional controllers if required, as well as the introduction of dynamic and flexible staff rostering.

Among the large number of human factor effects of this crisis, fatigue has been identified by EASA as a major hazard for flight safety during the shutdown and during the return to service or normal operations [1]. As this crisis is unprecedented, no pre-defined answers are directly available. Managing ATCO fatigue will therefore be a key aspect during and after the pandemic, in order to ensure both safe and healthy working conditions. This paper reviews the main risk factors of the pandemic on ATCO fatigue and proposes some recommendations to manage this risk.

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2 Risk of Fatigue in ATM

Fatigue is acknowledged as one of the major risks in ATM, both for flight safety and for employee health and well-being. A large part of fatigue in ATM is caused by the employees' irregular hours, which adversely affect their body clocks. The body clock, located in the suprachiasmatic nucleus of the hypothalamus, regulates daily variations in numerous physiological processes such as the sleep-wake cycle, body temperature and hormone release, as well as cognitive performance [2]. In a normal situation, the body clock is synchronised on a 24-h basis by daily exposure to light, diurnal physical activities and social interactions.

As ATM is a 24/7 service, ATCOs have to work irregular hours to cover the 24-h period. With shift-work, the body clock is no longer synchronised with the external time cues. ATCOs are working when they are meant to be asleep, and need to sleep when the body expects them to be awake. During night shifts, ATCOS work through the so-called window of circadian low (WOCL) (2 to 6 a.m.), in which most cognitive performance is significantly impaired. Subsequent diurnal sleep is poorer in quality and lesser in quantity. Early shifts are also known to impair performance and alertness as they are associated with a reduced quantity of sleep. The desynchronisation of the body clock results in a reduced quantity of sleep, poor quality of sleep and impairment of cognitive performance [3].

3 The Effect of the Pandemic on ATCO Fatigue

The COVID-19 lockdown has had a rapid and significantly adverse effect on both the working and living conditions of ATCOs. In particular, during the lockdown period, the time cues which are supposed to resynchronise the body clock were greatly reduced, with significant consequences on sleep. These effects are equivalent to the effects of jet lag [4]. This body clock desynchronisation and associated sleep deprivation are also known to have effects on immunity [5] and may reduce the ability of ATCOs to fight infectious diseases. COVID-19 also has a direct impact on fatigue: chronic fatigue has been reported as an after-effect on patients with even mild symptoms of COVID-19 [6].

In addition to the direct effects of the lockdown on the body clock, the risk of fatigue in ATM is increased by several other factors. In some ANSPs, the reduction in the number of available staff potentially means that the remaining staff are working longer and thus more intense hours. In other ANSPs, all staff are available and fewer position are manned, and therefore ATCOs are rostered for long duties with very little time on position. Furthermore, COVID-19-related measures may result in a longer, more fatiguing working day, with social distancing, isolation behind Perspex panels, restrictions on socialising/entertainment, and management pressures. Given the need to support their organisation in a crisis, people may feel under pressure to work when they should not in fact be compromising the fragile reporting of fatigue, which had only just started to be implemented in ATM.

In addition, COVID-19 effects many aspects of personal life, which in turn may effect general physical and mental fitness for duty. In particular, the uncertainty about the future of their employment could produce significant stress, which in turn could lead to sleep problems, fatigue and impairment of performance.

COVID-19 testing and health screening adds an additional process to the working day and a delay to the start of productive work. It may interfere with the ability of employees to organise their day, not least because of an inability to control how long the screening takes. It introduces an element uncertainty – what if you or colleague tests positive?

The consequence of ATCO fatigue was already visible on the rate of fatigue reports in April-May 2019, which were higher than the previous three-year average (Fig. 1) (EUROCONTROL, 2019).

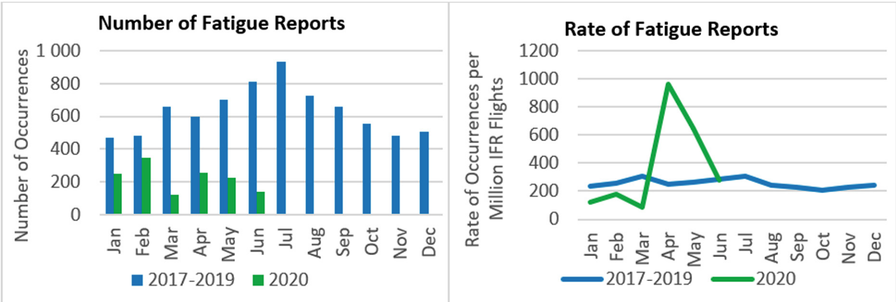

Fig. 1. Number and rate of ATCO fatigue reports from 2017 to 2020 [1]

The return to normal operation is still uncertain, and new fatigue problems are being reported owing to boredom or lack of motivation in the face of low levels of traffic, new fears of deskilling, or increased pressure of work owing to the financial crisis. Reductions in staffing levels and the introduction of new COVID-19- related tasks may lead to more tasks being carried out per person (more task variation). These tasks may be unfamiliar and therefore more demanding on individuals, who may not be well suited, trained or qualified for the activities they are subsequently required to carry out. Individuals may also be reluctant to point out this fact, under pressure to both support their organisation and remain in employment.

4 Fatigue Management During the COVID-19 Crisis and in the Post-cOVID-19 Period

The notion of shared responsibility is key to fatigue management.

As fatigue is affected not only by work-related aspects but also by non-professional factors, fatigue management has to be regarded as the shared responsibility of the organisation and the air traffic controller (ATCO). The responsibility of the organisation is to implement work schedules which enable controllers to perform their duties safely and provide fatigue management education and awareness training for all employees involved (in operations, support, safety management, etc.). For their part, ATCO are responsible for managing and reporting their fatigue.

In the context of the COVID-19 pandemic, the implementation of appropriate fatigue risk management principles is even more critical than in a normal situation. In addition to this prescriptive approach, CANSO, ICAO and IFATCA have recently issued recommendations for the implementation of fatigue risk management systems (FRMS) for air traffic service providers (ATSPs) [7]. FRMS is defined as "*data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles, knowledge and operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness*".

In Europe, EASA has issued a new regulation, which took effect in January 2020 (2017/373) based on ATM-related ICAO standards and recommended practices (SARPs).

Proactive fatigue management in ATM is therefore a key aspect with a view to emphasising and increasing the focus on ATCO fatigue in this unpredictable context. In particular, encouraging employees to acknowledge and communicate their fatigue through fatigue reporting is a way of monitoring fatigue levels and identifying the risk of fatigue. The analysis of fatigue reports should enable management to identify the main areas of risk and decide on appropriate mitigation measures. Assessment of the risks of fatigue associated with duty rosters is also a key aspect of fatigue management, especially in the context of the pandemic, as there may be pressure from organisations to define more cost-effective rosters. A number of approaches could be envisaged in order to assess rosters, ranging from scientific guidelines on rostering to the use of biomathematical models. These tools should, however, be supported by scientific expertise, as they have inherent limitations which need to be taken into account.

Another key aspect of fatigue management is to inform employees about these increased risks, highlighting the difficulties imposed by the pandemic. ATCOs and managers should be provided with specific initial and recurrent training in order to develop a shared representation of fatigue problems among organisations and provide appropriate strategies for managing the risk of fatigue.

5 Conclusion

Although the COVID-19 pandemic has drastically reduced air traffic, it has not removed or even reduced the problem of fatigue in ATM. The pandemic has undoubtedly increased uncertainty, anxiety and stress for people in general, and has had significant consequences which need to be examined. The economic crisis which is affecting all ANPs and the pressure to reduce costs should not be allowed to hide problems or delay the deployment of fatigue management systems. It is vital that we continue to collect data on fatigue. Employees must feel confident to declare their fatigue without fear of consequences in terms of their employment. Senior managers need to commit to minimising anxiety in the workforce as far as possible and must recognise the impact of reduced well-being. Additional factors are likely to contribute to fatigue in the recovery period. A holistic approach to fatigue management will be more important than ever in this period. Given the safety criticality underlying fatigue, well-being and stress, excessive financial cutbacks should not be made in fatigue management investments and budgets.

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Promoting Occupational Safety, Health, and Well-Being in Emergency Medical Services

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Abstract. The work of emergency medical service (EMS) workers is physically and mentally stressful. EMS workers sustain more occupational injuries than the general working population. At the same time, small and medium-sized enterprises (SMEs) typically suffer from a lack of time and competence in managing occupational safety, health, and well-being (SHW). The aim of this study was to investigate and promote the SHW of EMS workers in a small Finnish company. Data were collected through interviews, a survey, and a workshop. The results showed that SHW stress factors were mainly related to work ergonomics, physical workload, and the threat of violence. During the workshop, measures to promote SHW were suggested, and a related action plan was devised. This study provides knowledge regarding SHW risks, resources, and stress factors in EMS work and suggests measures for promoting SHW. The results can be used in EMS and other health-care organizations.

Keywords: Occupational safety, health and well-being · Emergency medical services · Small and medium-sized enterprises · Risk assessment

1 Introduction

When promoting safety in health-care and emergency medical services (EMS), the focus has traditionally been on patient safety [1]. However, the work in EMS is physically and mentally stressful and may negatively affect the occupational safety, health, and well-being (SHW) of employees [1–3]. According to a British study [4], the mental health and well-being of EMS personnel appear to be compromised.

EMS workers have higher levels of occupational injuries than the general working population in the private sector [5]. They also face risks of physical overexertion from patient handling, dangers from roadway incidents, verbal abuse and physical violence by patient, the threat of violence, and possible symptoms of post-traumatic stress disorder [2, 6–9]. The psychological burden of EMS professionals is particularly high, as they are exposed to situations that involve high emotional stress levels [3]. This may negatively affect not only their own SHW but also patient safety [3].

At the same time, small and medium-sized enterprises (SMEs) are characterized by a higher injury frequency than larger companies, especially when considering fatal

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accidents [10]. The traumatic fatality rate in small businesses is significantly higher than in larger ones [11]. According to a Danish empirical study, the physical work environment is more hazardous in small enterprises, and the quality of occupational health and safety (OHS) management systems and workplace assessment are worse in small than in large enterprises [12]. Small enterprises typically suffer from a lack of resources, time and competence in managing occupational safety and health [13].

According to OHS regulations in Finland [14], employers must identify hazards caused by work, working hours, work environments, and working conditions. They must also assess the risks to employees' health and safety if the hazards cannot be eliminated. Moreover, they are obligated to analyze workload factors that endanger employees' health and eliminate or reduce the risks. They must also organize adequate orientation for the employees.

Based on a Finnish study [1], employers should provide proper personal safety equipment for all employees and take workers' well-being into account in governance. Immediate supervisors' positive attitude toward safety affects employees' working methods. It suggests to study safety in EMS further, for example the role of employer, supervisors and employees in promoting safety. There is still a need to promote SHW in EMS and in SMEs. The aim of this study was to investigate and promote the SHW of EMS workers in a small Finnish company.

2 Materials and Methods

The case company of this study was a small Finnish private EMS company that is willing to promote its employees' SHW. The company has 22 employees and two employer representatives, all of whom participated in the study. Two temporary employees also participated. The orientation process of this company has an occupational safety component, which includes the threat of violence. Moreover, there are clear procedures for violent situations, which are regularly reviewed.

The researchers coordinated the development process of SHW action plan and data collection. Data were collected through an e-survey, interviews, and a workshop during November and December 2020. Participants were informed ethics of the study and they signed the consent for participation.

A descriptive analysis of the gathered data was performed. The aim of the survey and interviews was to identify areas that needed to be discussed and developed in the workshop.

The questionnaire used for the survey was based on the Risk Assessment in Workplaces Workbook [15]. It consisted of 25 SHW risk items, including physical work environment and working conditions, chemical and biological hazards, and physical and psychosocial loads. Each item was rated on a three-point scale, where 1 represented *risk exists and needs to be managed*, 2 represented *risk is under control*, and 3 represented *no risk*. The questionnaire was distributed to all employees and to two employer representatives, and 26 completed questionnaires were returned. One of the questionnaires was completed in group work with the participation of the employer and occupational safety and health representatives.

Three group interviews were conducted with employee representatives (n = 8) and one with the employer. They were semi-structured interviews based on a theoretical framework of concepts of structural empowerment (opportunity, information, support, resources, formal power, and informal power) and psychological empowerment (meaning, confidence, autonomy, and impact). The concept of empowerment was based on Laschinger et al. [16], who showed that empowerment directly affects job strain and job satisfaction. The interviews concerned SHW resources and stress factors originating from work, the work community, and the worker.

A remote workshop was organized in collaboration with the employees and the employer with 24 participants to discuss the results of the survey and the interviews and co-creatively develop an action plan to promote SHW. After the workshop, feedback questionnaires were sent to the participants.

3 Results

3.1 Interviews

The results of the three group interviews showed that a sense of work community and a good work atmosphere were considered key job resources. A low worker turnover and the relatively small size of this work community contributed to the emergence of a team spirit and open dialogue. The interviewees also emphasized that they treated each other fairly and equally irrespective of education, work role, or form of employment. Some interviewees likened the work community to a family where even difficult issues could be openly discussed. The value of positive verbal feedback and the desire to have more in the work community was another pattern emerging from the interviews. Participants also noted that work shifts were arranged with people who knew and understood each other well. Moreover, interviewees positively noted that wishes concerning days off were taken into consideration and managed flexibly.

Physical stressors at work that were highlighted in the interviews included lifting and carrying patients without proper lifting equipment and in difficult environments, work ergonomics, irregular working hours, long shifts, and prolonged sitting during work shifts. There was also a feeling of haste in the work, while others reported feeling burdened by remaining idle for long periods.

Potentially violent situations caused mental strain. Many interviewees reported that they discussed situations that they encountered with their work partners and other colleagues while still on the shift. It was also possible to request a defusing discussion based on a defusing method, for which there were trained instructors in the work community. Good atmosphere and receiving social support were strongly emphasized as important for a harmonious work community.

Interviewees considered the development of work-related skills important and reported that the employer promoted it efficiently. In addition to personal study, the work community organized training sessions and encouraged the acquisition of new professional qualifications. Interviewees described a culture of open discussion that fostered learning, new ideas, and opportunities for development, although some felt that their ideas and suggestions for development were not always heeded.

3.2 Survey

Respondents felt that risk management needed to be improved in several areas, including the threat of violence, harassment and other inappropriate behavior, awkward work postures, manual handling and moving of objects or patients, insecure job contracts, possibility to breaks during work shift and work pace, social and ethical load (work includes demanding human relations or difficult value judgment), and the risk of infection. The numbers of respondents rating each item as 1 (*risk exists and needs to be managed*) are shown in Fig. 1.

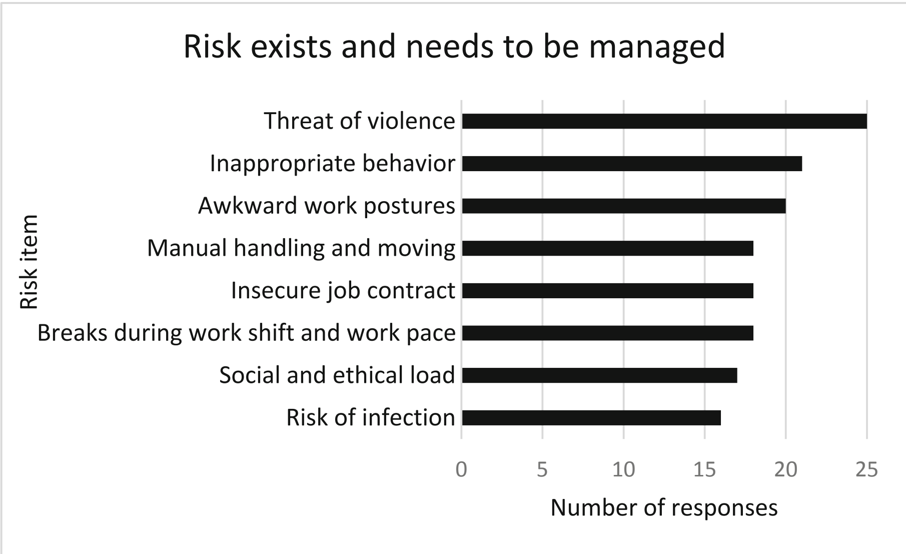

Fig. 1. Risks that needed to be managed according to most respondents.

3.3 Workshop

The interview and survey results were presented in a workshop and discussed in small groups. The main themes of the discussions were 1) work environment and tools, 2) contents of the work and work arrangements, and 3) work community. The participants suggested several development actions pertinent to each theme and finally selected the most relevant for further development. Based on the discussions, the following actions were decided, and responsible persons or teams were assigned:

- Assuming responsibility: clearer definition of work roles and responsibilities
- Communication: improvement of the communication process (what, when, and to whom to communicate) and feedback system
- Durability of tools: purchase of durable tools

- Orientation/introduction to equipment and tools: improvement of the orientation process
- Self-directed review of instructions: development of rules for regular self-directed reviews

It was decided that the development actions would be evaluated in the near future. Based on the feedback, the participants perceived the workshop and group discussions as pleasant and interactive even though they were conducted remotely. Moreover, they felt that they were able to participate in the suggestions and decisions on the development actions.

4 Discussion

This study was conducted to investigate and promote the SHW of the EMS personnel of a Finnish company. There are both physical and psychological risks involved in EMS work [1–9]. According to OHS regulations [14], employers must conduct risk assessments and take actions to minimize the risks to employees' safety and health, as well as providing orientation. With regard to ergonomics, employers must provide appropriate devices and guidance to employees to minimize the risk of physical overexertion. On their part, employees must follow the employers' instructions and ensure their fitness for work.

The results of the survey showed that almost all respondents felt that their work involved risks related to the threat of violence, inappropriate behavior, and awkward work postures that needed to be managed. The employees believed that risks could be managed through training and developing procedures for such situations. The questionnaire thus functioned as a risk assessment tool for the company [14]. The fact that the entire personnel participated in the survey offered a comprehensive picture of the risks in the company.

The results of the interviews also showed that SHW stress factors were mainly related to work ergonomics, physical workload, and violence or the threat of violence. The most valuable SHW resources were a sense of community, a good work atmosphere, and social support from coworkers and managers. This is in line with a Finnish study on EMS that reported that most respondents were content with their work shifts and related planning and with the workplace atmosphere [1]. According to the same study, most respondents had encountered violence or the threat of violence, and almost half of them had sustained injuries due to lifting or moving during the previous 12 months.

The SHW development actions were co-created with the employees in a workshop based on the group interview and survey results. An action plan was collectively devised based on the most relevant development actions. The selected actions were related to responsibilities, communication, tools and equipment, and regular reviewing of instructions. All actions will be promoted by the teams responsible for ensuring the realization of the development plan. The development actions differed from the development needs that emerged from the survey and interviews. This may indicate that the employees consider them occupational safety and health issues and therefore the responsibility of the employer. Issues related to well-being might be perceived as easier to tackle through collaboration in the workplace. Moreover, the theoretical framework of the interviews was based on the theory of organizational and psychological empowerment [16]. In contrast, despite discussing several themes related to empowerment in the interviews, the workshop focused more closely on practicalities rather than organizational changes in general.

The development actions devised in the workshop had some differences to an earlier Finnish study [1]. The earlier study emphasize training but in our study the development action considered independent reviewing of instructions. Most respondents in that larger study [1] had received adequate equipment orientation, but orientation to equipment and tools was one of the development actions in our study.

This study has some limitations. First, it involved only one SME. Although the entire personnel responded to the questionnaire and participated in the workshop, the number of participants was still low and the results cannot be generalized to all EMS organizations. Moreover, the development period was quite short, and the development has not yet been evaluated. The realization of the development actions will be evaluated by the company in the near future. However, this is beyond the scope of this study.

Despite its limitations, this study provides valuable knowledge regarding SHW risks, resources, and stress factors in EMS work and suggests measures for promoting SHW. The results can be used by EMS organizations and SMEs and may also be useful for other health-care organizations.

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An AHP Method Study on the Migrant and Refugee Employees Occupational Health and Safety Issues in Turkey

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Abstract. Many people have emigrated to Turkey rom Syria civil war, and turmoil in the Middle East. Including the major of the Syrians, there are about 6 million regular-irregular migrants. More than 3 million immigrants and refugees are in the work market, more than 2.5 million are illegal. Illegal migrants cannot benefit from OHS services, generally receive less wages, in worse conditions, they work long hours. They are often subjected to human rights violations, harassment, and human trafficking. It is important to know the order of importance for the solution of the problems. In this study, the data were obtained through the Search Conference and the AHP study and evaluated by comparing them with each other according to the order of importance of the problems. The problems arise by 58% government practices, 29% employers, 13% personal mistakes and negligence of workers.

Keyword: Migrant worker · Workplace conditions · Environmental conditions · Law · OHS issues · Introduction

1 Introduction

However, as soon as the arrival of large number of foreigners, Turkey has caught unprepared and as native labor, both are adversely affected by the newcomers. Six million immigrants and refugees constitute 7.3% of Turkey's population, came to Turkey for work or safety [1]. A total of 2 million 800 thousand people aged 15 years and over are employed and constitutes 8.9% of the 31 million 629 thousand native work force [2].

This study summarizes the current literature on OSH factors of migrant workers, compares them with native workers, and lists the problems of health and safety outcomes in order of importance. The results of our previous Search Conference on the subject, were compared with the AHP (Analytic Hierarchy Process) method study, one of the Multi Criteria Decision Making Methods, and a high level of correlation was found. In both studies, the OHS problems of migrant workers were ranked in order of importance.

According to ILO estimates, the ratio of immigrant women to total immigrant workforce in the world is 43%, the ratio to the total Turkish workforce is 4%, and the ratio to the total domestic female workforce is 8%. Women are six times more likely to participate in domestic work abroad than men [3].

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2 Search Conference Study

On the organization of Search Conference participants consists of, Ministry of Family, Labor and Social Services, General Directorate of Occupational Health and Safety, Ministry of Internal Affairs Directorate of Migration Management, Unions of Universities Working on Migrant Workers, Trade Unions, Immigrant Non-Governmental Organizations, Red Crescent, International Labor Organization (ILO), Syrian Academicians, Migrant workers and OHS Experts. 60 OHS problems obtained through the literature study on migrant workers were presented to the participants. The list of substances consisting of 40 items, voted by the participants OHS problems of migrant workers in Turkey unordered list has been created. The 40-item problem list was re-voted, scored, weighted, and the overall importance ranking of the OHS problems of migrant workers in Table 1 was established.

Table 1. Search conference weighted migrant worker OHS issues ranking list.

Search conference issues order			
No	Criteria	Points	General importance levels
1	Lack of Law, Charter, Regulation and Implementation	746,15	0,163748
2	Obligation to Work Unregistered	449,92	0,098738
3	No Long-Term Immigration Policy	274,85	0,060318
4	Lack of Communication Concept	260,95	0,057267
5	Lack of OHS Training	220,87	0,048472
6	Not Establishing a Special Control System for OHS Training	218,20	0,047886
7	Difficulties of Working Conditions	212,78	0,046696
8	Working in Difficult Conditions in Unregistered Workplaces	149,14	0,032730
9	Not Reporting Work Accidents Deliberately	132,80	0,029144
10	OHS Problems of Informal Employees	130,68	0,028679
11	Qualification Certificate Equivalence Acceptance Issues	109,67	0,024068
12	Dissemination of OHS Trainings	93,98	0,020625
13	Trainings are not Multilingual	92,07	0,020205
14	Sexual Harassment, Mobbing	90,46	0,019852
15	Low Wage According to Native Workers	90,23	0,019802
16	Vocational Competence Planning Lack	88,02	0,019317
17	Lack of Experience of Workers and Employers	75,20	0,016503
18	Lack of Archive System	71,64	0,015722
19	OHS Problems Arising from Cultural Differences	67,70	0,014857
20	Gender Discrimination and Child Labour	66,21	0,014530

(*continued*)

Table 1. (*continued*)

Search conference issues order			
No	Criteria	Points	General importance levels
21	Insufficient Statistics	64,12	0,014072
22	Not Making Use of Cases Experienced in the Past	60,93	0,013372
23	Adaptation Problem	60,63	0,013306
24	Health Screening Deficiency	60,47	0,013271
25	Local Workers' Negative Perceptions for Migrant Workers	59,78	0,013119
26	Limitation of Movement	56,39	0,012375
27	Not Implementing one Immigrant Employment Obligation System for Ten Native Workers	54,49	0,011958
28	Not Knowing Their OHS Rights	53,82	0,011811
29	Denial of Permission to Establish a Union	53,77	0,011800
30	No Overtime Wage and Long Working	53,11	0,011655
31	Long License Acceptance Period	50,30	0,011039
32	Inadequate and Incomplete Job Descriptions	48,41	0,010624
33	Signs and Warnings are not Multilingual	46,00	0,010095
34	Lack of OHS Training of Workers with Work Permits	45,45	0,009974
35	Communication and Language Problems Not Handled Separately	31,54	0,006922
36	Low General Education Levels	29,43	0,006459
37	The Lack of OHS Culture	28,59	0,006274
38	Not to Accept Universal Definitions of Immigrant-Refugee	25,83	0,005669
39	Culture of Fatalism	19,18	0,004209
40	Forcing to work out of expertise	12,93	0,002838
	Total	4556,69	1,000000

The order of general significance values in Table 1 is presented graphically in Fig. 1. The first item, Law, Regulation, Regulation and Implementation Deficiencies, was the problem item that the participants unanimously emphasized.

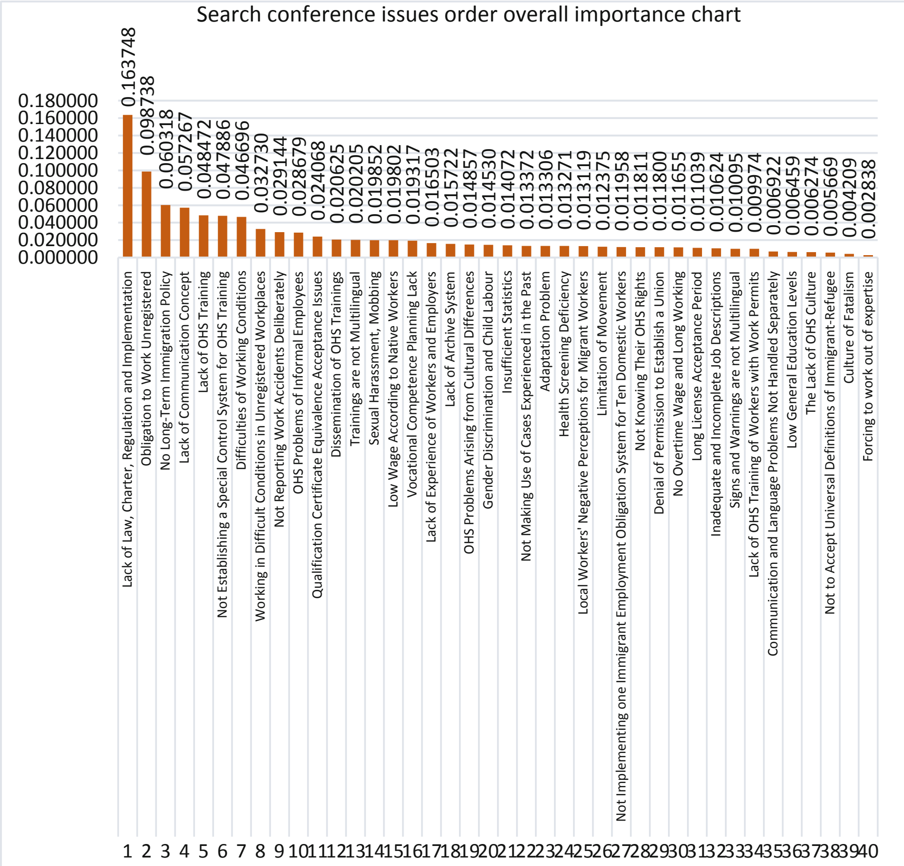

Fig. 1. Migrant worker OHS issues, search conference overall severity ranking chart.

In the list of issues obtained from the search conference study, it was seen that the data obtained in the study conducted among the three groups consisting of the main stakeholders, the state, employers and migrant workers, were clustered as presented in Fig. 2.

a) Problems arising from the obligations of state: total weight of 0.560830, 17 problem (%56 percent) (1, 3, 4, 5, 6, 10, 11, 12, 16, 18, 21, 24, 27, 29, 31, 35, 38) numbered items,
b) Problems arising from the obligations of employer's: total weight of 0,258021, 14 problems (%26 percent) (7, 8, 9, 13, 14, 15, 17, 20, 22, 30, 32, 33, 34, 40) numbered items,
c) Problems arising from the obligations of employees: total weight of 0,181149, 9 problems (%18 percent) (2, 19, 23, 25, 26, 28, 36, 37, 39) numbered items.

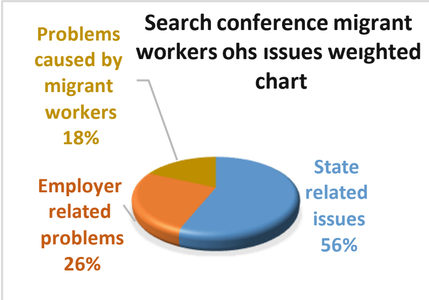

Fig. 2. Search Conference, weighted chart of the effect of the parties on OHS problems.

The order of AHP study overall importance values in Table 2 is presented graphically in Fig. 3. The first item, Lack of Law, Regulation, Regulation and Implementation, was the problem that the participants insisted on, as in the search conference.

Table 2. AHP multi-criteria decision-making method, ranking table of importance of migrant workers' OHS problems.

AHP super decision issues order		
No	Criteria	Overall importance
1	Lack of Law, Charter, Regulation and Implementation	0,141457
2	Lack of OHS Training	0,096801
3	Working in Difficult Conditions in Unregistered Workplaces	0,078264
4	Communication and Language Problems Not Handled Separately	0,071124
5	Trainings are not Multilingual	0,053409
6	Dissemination of OHS Trainings	0,046279
7	OHS Problems of Informal Employees	0,045026
8	Difficulties of Working Conditions	0,044623
9	Signs and Warnings are not Multilingual	0,042152
10	Vocational Competence Planning Lack	0,040157
11	Not Implementing one Immigrant Employment Obligation System for Ten Native Workers	0,031432
12	The Lack of OHS Culture	0,030371
13	Not Establishing a Special Control System for OHS Training	0,027514

(*continued*)

Table 2. (*continued*)

AHP super decision issues order		
No	Criteria	Overall importance
14	Obligation to Work Unregistered	0,020389
15	Gender Discrimination and Child Labour	0,018539
16	Lack of Communication Concept	0,017996
17	Lack of Archive System	0,017708
18	Lack of OHS Training of Workers with Work Permits	0,016467
19	No Long-Term Immigration Policy	0,015831
20	Qualification Certificate Equivalence Acceptance Issues	0,015067
21	Inadequate and Incomplete Job Descriptions	0,013673
22	Long License Acceptance Period	0,012939
23	No Overtime Wage and Long Working	0,012680
24	Insufficient Statistics	0,011652
25	Local Workers' Negative Perceptions for Migrant Workers	0,010768
26	Not Knowing Their OHS Rights	0,009590
27	Forcing to work out of expertise	0,008890
28	Not Making Use of Cases Experienced in the Past	0,008618
29	Sexual Harassment, Mobbing	0,007613
30	Low General Education Levels	0,005689
31	Denial of Permission to Establish a Union	0,005411
32	Culture of Fatalism	0,004055
33	Health Screening Deficiency	0,003835
34	Not to Accept Universal Definitions of Immigrant-Refugee	0,003488
35	OHS Problems Arising from Cultural Differences	0,002770
36	Not Reporting Work Accidents Deliberately	0,002464
37	Adaptation Problem	0,001799
38	Lack of Experience of Workers and Employers	0,001476
39	Low Wage According to Native Workers	0,001300
40	Limitation of Movement	0,000686
	Total	1,000000

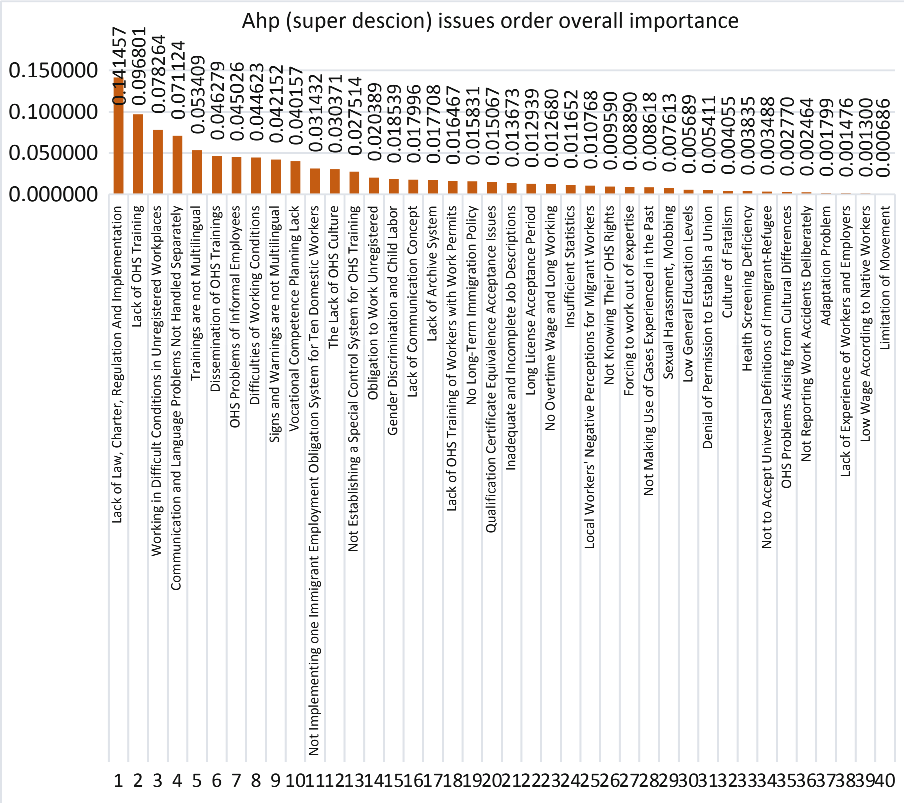

Fig. 3. Migrant worker OSH problems, AHP study overall severity ranking.

The contributions of the government, employers and migrant workers, who are the main stakeholders in the weighted list in the AHP study, to OSH issues are shown in Fig. 4, these are as follows:

a) Problems arising from the obligations of state: total weight of 0,603717, 17 problem (%60 percent) (1, 2, 4, 6, 7, 10, 11, 13, 16, 17, 19, 20, 22, 24, 31, 33, 34) numbered items,
b) Problems arising from the obligations of employer's: total weight of 0,310168, 14 problems (%31 percent) (3, 5, 8, 9, 15, 18, 21, 23, 27, 28, 29, 36, 38, 39) numbered items,
c) Problems arising from the obligations of employees: total weight of 0,086117, 9 problems (%9 percent) (12, 14, 25, 26, 30, 32, 35, 37, 40) numbered items (Fig. 4).

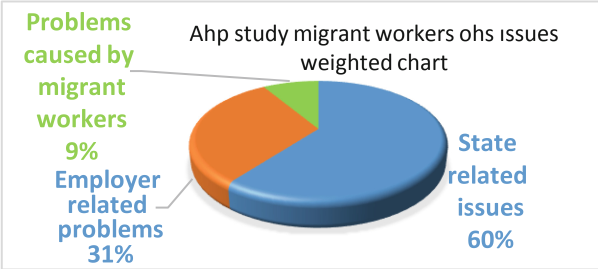

Fig. 4. AHP study, weights graphic of the effect of the parties on OHS problems.

AHP, due to its nature, allows up to 15 pairwise comparisons to give a healthy result. For this reason, subgroups are created in the comparison list in cases where large number of binary comparisons are required. Due to the nature of the AHP method, the number of binary criteria to be compared in the comparison tables should be 9 at most in order to make a healthy comparison. In practice, academics usually make paired comparisons with a maximum of 9 criteria, and we did the same in our study.

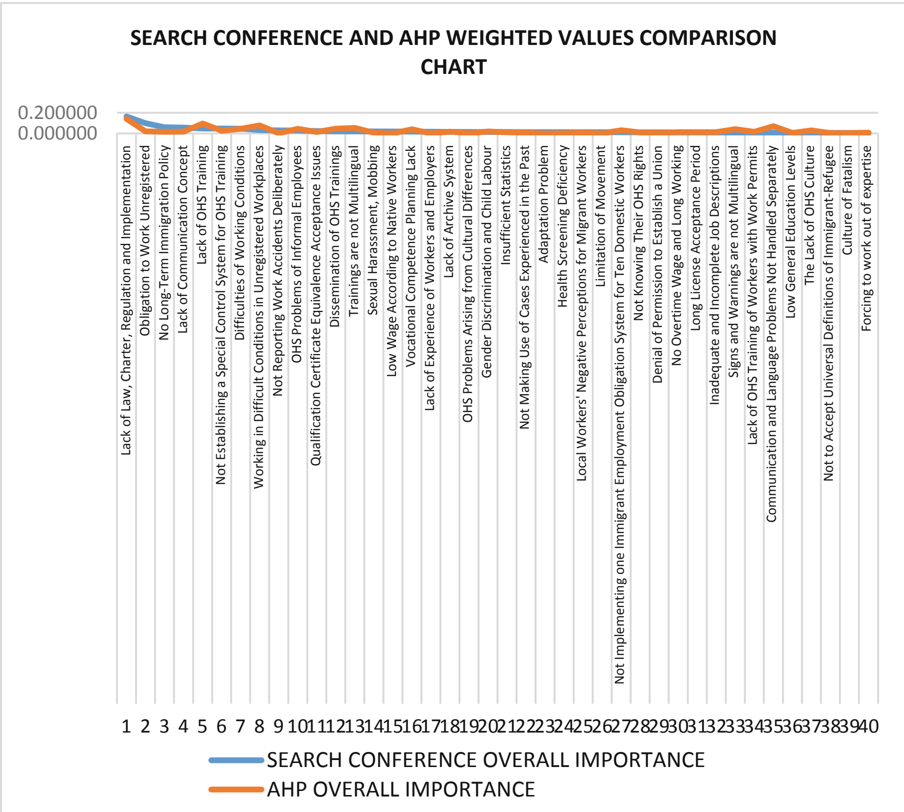

Fig. 5. Comparison chart of AHP study and Search Conference general significance levels

Major Groups with 7 criteria were formed under the headings of Lack of Legislation and Implementation, State Policy, Social Problems, Risk Factors, Lack of Archives, Lack of Audit and Registration Problems. In the Super Decision program, 21 pairs were weighted by making comparisons, and Table 3 was prepared.

Table 3. Comparative list of the main severity levels obtained from the main groups, search conference, and AHP studies.

Main criteria comparison		Search con	AHP
1	Lack of legislation and implementation	0,237051456	0,312174872
2	Government policy	0,146296983	0,098523133
3	Social issues	0,084126855	0,027067295
4	Risk factors	0,182764243	0,278482407
5	Lack of archive	0,07293891	0,043287245
6	Lack of inspection	0,104863399	0,087196251
7	Registration	0,171958154	0,153268796

The weighted values obtained in the search conference were collected according to the above grouping and the weighted score values of the groups were created separately, the weighted score values of the main groups were formed by adding the subgroup weight values of the Main Groups in the AHP study. A combined graph of the weighted values of both studies was drawn. As is seen Fig. 5 that, the ranking chart according to the weight values of the Main Groups formed in the Search Conference and AHP studies overlaps.

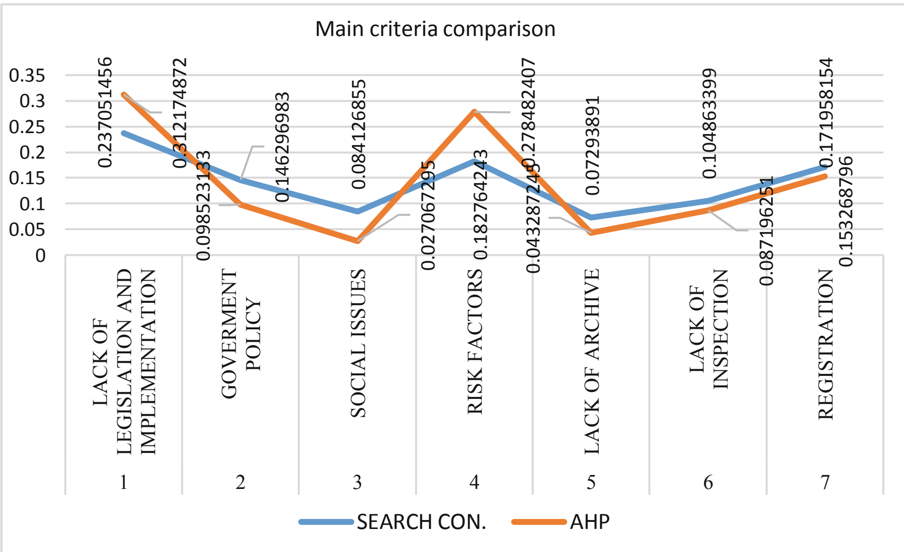

Fig. 6. Comparison chart of main groups general significance levels.

3 Conclusion

Despite the economic advantages that migration provides to countries, migrant workers are at risk of many OSH related to professional, legal status, migration policies, cultural and linguistic barriers. It is the responsibility of governments and employers, as well as the global community, to protect the health and safety of all workers. They are paid less than native workers, they work longer hours, in worse conditions, and are often subjected to human rights violations, harassment, human trafficking and violence. Migrant workers around the world have occupational exposure and working conditions that lead to adverse health consequences, workplace injuries and deaths. The health and safety inequalities of migrant workers are a result of environmental and occupational exposures, linguistic/cultural barriers, access to healthcare, documentation status, and the political climate of the host country.

For the approximately 2.5 million migrant workers who work illegally, the situation is extremely tragic. There is no concept of OHS services for these people.

The OHS problems of migrant workers cannot be solved without formulating solution strategies for the seven headings we have obtained from the Search Conference and AHP study, “Lack of Legislation and Implementation, Government Policy, Social Issues, Risk Factors, Archive Failure, Lack of Inspection, Registration” respectively If we expand these topics a little more, the problems are better defined according to the importance order below,

Obligation to Work Unregistered
No Long-Term Immigration Policy
Trainings are not multilingual
Lack of Communication Concept
Dissemination of OHS Trainings
Lack of OHS Training
OHS Problems of Informal Employees
Difficulties of Working Conditions

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