Advances in Intelligent Systems and Computing 605

Richard H.M. Goossens *Editor*

Advances in Social & Occupational Ergonomics

Proceedings of the AHFE 2017 International Conference on Social & Occupational Ergonomics, July 17–21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA

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Advances in Human Factors and Ergonomics 2017

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8th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences

Proceedings of the AHFE 2017 International Conference on Social & Occupational Ergonomics, July 17–21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA

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Preface

An exploration of how ergonomics can contribute to the solution of important societal and engineering challenges, Advances in Social and Organizational Factors discusses the optimization of sociotechnical systems, including their organizational structures, policies, and processes. It includes coverage of communication, crew resource management, work design, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work paradigms, organizational culture, virtual organizations, telework, and quality management.

This book provides research on urban infrastructures and how to shape urban spaces, including stadiums and museums. It covers warning systems in cars, voice-based interfaces, and the positive effects on manufacturing processes available from health informatics and management systems. Several chapters examine the role human factors can play in counter-terrorism efforts and in interpreting deceptive behaviors. They provide suggestions on how to improve enterprise resource planning systems and stress the importance of lifelong learning, personalized learning, and work-life balance. This book also highlights issues with special populations, detailing how to design and adapt products and work situations for these groups. In addition to exploring the challenges faced in optimizing sociotechnical systems, this book underlines themes that play a role in all the challenges and how they are linked to each other. It concludes with an exploration of emotional ergonomics and the important positive effects of making people happy and healthy. With chapter authors from around the globe, this book supplies a broad look at current challenges and possible solutions. This book contains a total of four sections that cover the following topics.

I. Macroergonomics Solutions of Engineering Management Challenges
II. Human Aspects of Change Management and Implementation
III. Musculoskeletal Aspects of Social and Occupational Ergonomics
IV. Social and Occupational Ergonomics Applications

The organizers would like to thank all the authors for their contributions. Each of the chapters was either reviewed by the members of the editorial board or germinated by them. For these, our sincere thanks and appreciation go to the members of the board listed below.

We sure hope this book contributed to increase in knowledge in the field of social and organizational ergonomics and that you find the papers in this book interesting and helpful to you and your work.

July 2017 Richard H.M. Goossens

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Macroergonomics Solutions of Engineering Management Challenges

Psychosocial Aspects of New Technology Implementation

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Abstract. New technology is dramatically changing the workplace by allowing companies to increase efficiency, productivity, quality, safety, and overall profitability. An effective new technology implementation is required for companies to compete successfully in the marketplace. Time and money wasted on unsuccessful and improper new technology implementation is contrary to the overall goal of improving the competitiveness and profitability of the company. This paper proposes a technology implementation approach utilizing teams and teamwork. Teams and teamwork have been recommended as a way to improve efficiency, productivity, quality, safety, profitability, and employee satisfaction [1]. New technology challenges the current implementation methods and techniques. To effectively utilize these new technologies it is best to consider all the factors involved in the implementation process; most importantly the individual human elements involved. It is recommended to utilize a cooperative team oriented approach to new technology implementation, which relies heavily on obtaining employee inputs and participation throughout the entire process. By doing this; it is hoped that the new technology can be implemented in the most effective way possible.

Keywords: Psychosocial · New technology · Teamwork · Efficiency · Productivity · Quality · Safety · Profitability · Employee satisfaction · Ergonomics · Human factors · Balance theory model · Applied field research · Manufacturing · Assembly · Production processes

1 Introduction

This paper proposes a technology implementation approach utilizing teams and teamwork. Teamwork has been recommended to organizations as a way to improve productivity, quality, and employee satisfaction [1].

2 The Model

The model to be utilized is based on achieving balance between the various implementation elements. This model is known as the Balance Theory Model of M. J. Smith and P. Carayon-Sainfort [2] and integrates the psychological and biological theories in an ergonomic framework.

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This model specifies that the working conditions and other factors outside of work, can create a stress on the individual. This stress can have physiological and psychological consequences. If the stress exceeds the individual's capacity, the stress can produce a negative effect on the individual which could result in a strain. This is a bad fit between the individual resources and the work demands. If the stressful exposure continues for a prolonged time period, then this can result in serious musculoskeletal disorders.

The factors involved in the implementation process are the new technology characteristics, organization structure, task factors, environmental characteristics, and the individual human factors involved (Fig. 1).

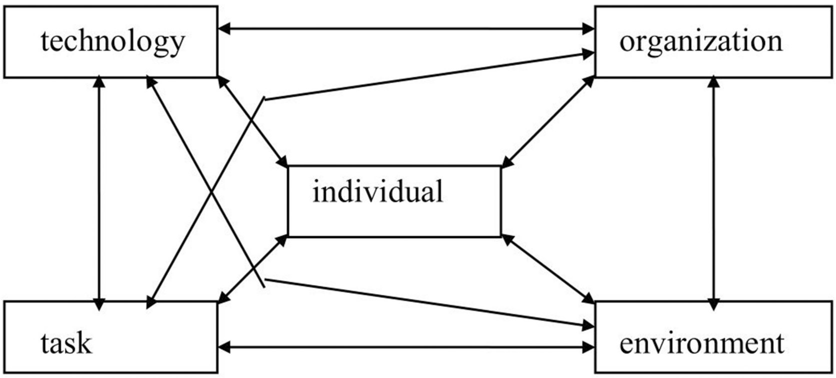

Fig. 1. The balance theory model of smith and carayon-sainfort [2].

The Balance Theory Model is as follows:

The Balance Theory Model is a system view concept for the various elements work. The Balance Theory Model shows the stress that working conditions can exert on the individual. These five elements of the Balance Theory Model all interact to define how work is to be performed. The individual is in the center of the Balance Theory Model. The individual has physical attributes and characteristics, previous experiences and knowledge, individual attitude and personality, and learned behaviors from which to draw from in order to cope with the working condition stress. The elements of task, technology, organization, and environment all influence the job content of work, the physical effort required of the individual, and the level of stress placed upon the individual [2].

In the model these factors interact in a systematic fashion to determine the success and effectiveness of the new technology implementation. This is a total systems model, in that any one factor can influence and affect the other factors.

3 Team Advantages

The Teamwork is one form of work organization that can have a positive effect on the various elements of the work organization; especially on the human elements; such as performance, productivity, motivation, attitudes, and health. Autonomous work groups (i.e. teams) have the authority to make work decisions, which resulted in increased personal commitment, improved cooperation, reduced absenteeism, and increased safety [3].

The advantages of using teams and employee involvement are to increase the potential for improving efficiency, productivity, quality, safety, profitability, employee satisfaction, and acceptance of change. Employee involvement affects the five major determinants of organizational effectiveness which are: motivation, satisfaction, acceptance of change, problem solving, and communication [4].

4 Participatory Ergonomics

Teamwork has been used in the implementation of participatory ergonomics in order to improve the working conditions for the employees. The use of teams to evaluate, design, and improve jobs is gaining widespread acceptance. Participatory ergonomics views the employee's participation and knowledge as critical [5]. Participatory ergonomics stresses worker's experience in problem solving. The employee's are in the best position to identify the problems in the work environment. The worker's involvement in the analysis and redesign of their work place leads to better solutions by utilization of the worker's knowledge to improve the process. Participatory ergonomics stresses employee empowerment and autonomy, by providing workers with more control over their work environment.

5 Employee Participation

The concept of employee participation in new technology implementation is to satisfy the employee's needs and therefore increase motivation and acceptance of the new technology to be implemented. Creating the proper environment to motivate employees and causing them to work harder will result in increased individual employee performance [2, 4, 7]. Therefore participation influences satisfaction and performance, and brings about an increased flow of information between individuals involved in the new technology implementation. Essentially employee participation is used in order to reduce the employee's resistance to change, and created an environment conducive to enhancing employee acceptance of the new technology.

6 Case Study

This model, involving teams and teamwork, was utilized on a new technology implementation in a manufacturing assembly facility. The project consisted of introduction of a new assembly method in a medium size manufacturing facility.

This implementation of new technology consisted of the following project scope:

(1) build a focus factory with capacity to produce 160 units per shift;
(2) convert a 38,000 square foot warehouse into manufacturing space;
(3) build a 5,000 square foot paint line building addition; and
(4) initiate and complete the project within a four month time frame.

7 Case Study Project Items

This case study consisted of the following project items:

(1) reinforce the existing building structure;
(2) install welding ventilation;
(3) install ¾ mile additional power and free paint conveyor;
(4) install nine “new concept” robotic weld cells;
(5) install a “new concept” overhead power conveyor system;
(6) install a new powder paint robotic paint booth;
(7) install three material paint drops, and
(8) construct new offices, lunch room, bathrooms, and locker room facilities.

8 Case Study Highlights Summary

Throughout this new technology case study the following processes were implemented: information sharing, employee participation, employee involvement, planning for change, High Involvement Management [4], and the Balance Theory Model [2].

The type of powered overhead conveyor system has never been utilized at the existing manufacturing facility. Therefore there was a high degree of uncertainty and uneasiness on the part of the management and employees in the manufacturing facility. Even though this powered overhead conveyor system has been proven to be successful in several similar mass production facilities. The current management and employees had to be convinced that a this was the best thing to do in order to ensure the long term profitability and survival of the organization.

In addition; the overall management and operational structure of the new assembly area was to be team oriented. This was a significant departure form the norm in regard to work group organization. Management had attempted to employ this team oriented approach in the past with very little success. It was thought that with this new conveyor and assembly method the time was right to attempt to employ a team oriented approach. This would be an empowered team oriented approach; in which the teams were empowered to run the entire assembly area. The team of employees working in the area would be empowered to make all day to day decisions related to the smooth operation of the area. All employees were already familiar with an employee incentive pay system, so therefore it was thought that total empowerment of the employees would result in greater employee satisfaction, improved employee motivation, and yield higher employee productivity and efficiency. The employees were also empowered to design their jobs in order to optimize their productivity and efficiency. The employees could therefore utilize peer pressure to attract like minded employees to their peer work group.

In regards to ergonomics; a participatory ergonomics approach was utilized in order to solve ergonomics problems in the assembly line environment. Participatory ergonomics consists of a small group of employees meeting in order to solve ergonomics problems which exist. Participatory ergonomics allows employees to be heard regarding ergonomic problems in the assembly area. Participatory ergonomics also give the employees the knowledge and access to expertise in order to solve the ergonomic problem. By listening to the employees opinions, and through cooperation between all the parties involved; ergonomics problems could be corrected in a timely proactive manner. The communication and sharing of information in critical to the successful utilization of participatory ergonomics. Participatory ergonomics is a useful tool to use to create employee participation and involvement, and also reduce the resistance to change with the implementation of new technology.

9 Conclusion

This model, involving teams and teamwork, explains a way in which new technology implementation can be successful; by the interaction of five different factors - technology, organization, task, environment, and individual. This model establishes a system to balance the bad aspects of new technology implementation with the good aspects of new technology implementation. The advantage of this model is that new technology can be implemented with a holistic “big picture” view of the project. Therefore all elements of the new technology implementation must be considered in order to determine the most effective implementation strategy for the new technology. Teamwork, participation, and employee involvement are critical to the successful implementation of new technology.

References

1. Lawler, E.E., Mohrman, S.A.: Quality circles: after the honeymoon. Org. Dyn. **15**(4), 42–54 (1987)
2. Smith, M.J., Carayon-Sainfort, P.: A balance theory of job design for stress reduction. Int. J. Ind. Ergon. **4**, 67–79 (1989). Elsevier Science Publications, The Netherlands
3. Trist, E.: The Evolution of Socio-Technical Systems. Ontario Ministry of Labor – Quality of Work Life Center, Toronto, Canada (1981)

4. Lawler, E.E.: High Involvement Management. Josey Bass Publications, San Francisco (1986)
5. Nora, K., Imada, A.: Participatory Ergonomics. Taylor and Francis, London (1991)
6. Smith, M.J., Carayon, P., Miezio, K.: VDT technology: psychosocial and stress concerns. In: Kave, B., Wideback, P.G. (eds.) Work with Display Units, vol. 86, pp. 695–712. Elsevier Science Publishers, The Netherlands (1987)
7. Coch, L., French, J.R.P.: Overcoming resistance to change. Hum. Relat. **1**, 512–532 (1948)

How to Make Maintenance Processes More Efficient Using Lean Tools?

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Abstract. This paper discusses the combined issues of lean thinking and maintenance in particular performance indicators to identify the impact of lean thinking within maintenance. Specific attention focuses on the contribution of lean thinking within an organization, the need for maintenance to align itself with the business objectives of the organization, and the need for performance measures to inform of improvement within the organization, and maintenance in particular, through lean tools and activities.

Keywords: Human factors · Human-systems integration · Systems engineering

1 Introduction

Today, the organizations must be flexible in their operations, capable of producing quality products and delivering the products to the customers with competitive price [1–6]. These demands emphasize the need for high levels of overall system reliability that include the reliability of human resources, machines, equipment, material handling systems, other value adding processes, and management functions throughout the manufacturing system [7–10]. Low productivity, downtime, and poor machine performance is often linked to inadequate plant maintenance, which in turn can lead to reduced production levels, increasing costs, lost market opportunities, and lower profits. These losses have given firms worldwide the motivation to explore and embrace proactive maintenance strategies over the traditional reactive firefighting methods [11–14]. One approach to improve the performance of maintenance processes is to implement lean tools.

The objective of this papers is to identify the different types of maintenance waste evident in the companies and to see how the identified maintenance wastes are reduced or eliminated by the lean tools. The structure of this paper is organized into five sections. The next section is literature on lean thinking review. The third section is literature on maintenance strategies and activities, and lean thinking within the maintenance process, review. The fourth section discusses the maintenance process from lean perspectives. The last section contains a conclusion of the paper and proposals for future research.

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2 Lean Issues

The philosophy of Lean and its practices have emerged as one of the most successful and widely used systems in today's world. Many researchers have recommended Lean as a very effective system for making an organization better and more capable. Lean can be considered from both a philosophical perspective, related to guiding principles or overarching goals, and from a practical perspective, as a set of management practices, tools, or techniques that can be observed directly [15]. In the book [16] the authors argue that a lean way of thinking allows companies to "specify value, line up value-creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively". Shah and Ward [17] define lean production as "an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability".

The focus of Lean is about waste elimination. Waste in Lean, is defined as anything that does not add value to the product or service from a customer's perspective [18]. Since waste elimination is one of the Lean objectives, it is crucial for companies to identify wastes relevant to: defects, waiting time, overproduction, transportation, inventory, unused creativity and over processing. To identify the waste and take actions striving for eliminating or limiting them, operational perspective needs to be applied. Lean from an operational perspective involves implementing a set of shop floor tools and techniques aimed at reducing waste within the plant. Such tools and techniques include, for example, setup time reduction, work standardization, kaizen, visual displays (e.g. 5S), Kanban and preventative maintenance.

Although lean manufacturing has its origins in the automobile manufacturing sector, other industries have adopted the practices to improve their own operations [19–23]. Analysis of literature and observation of businesses operations, led to formulation of the following thesis "transition towards a Lean production system requires fundamental changes in the maintenance operations". Lean does not work without highly reliable and predictable machines and processes. A failure in equipment or facilities not only results in loss of productivity, but also in a loss of timely services to customers, and may even lead to safety and environmental problems which destroy the company image. Lean Manufacturing requires equipment to be available on demand. The requirement leads to the revision of the traditional maintenance process in companies.

3 Lean Thinking and Maintenance

Companies are seeking to gain competitive advantage with respect to cost, quality, service and on time deliveries. The effect of maintenance on these variables has prompted increased attention to the maintenance areas as an integral part of productivity improvement [24]. The term "maintenance" is defined in standard EN 13306 as the "Combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function (function or a combination of functions of an item which are considered necessary to provide a given service)." By Khairy [25] the key objective of maintenance is "total asset life cycle optimization" and this objective must be attained in a cost - effective way and in accordance with environmental and safety regulation. Hence, that maintenance management must align with business activities at strategic, tactical, and operational levels [26]. Kans [27] has described maintenance management as activities in order to reach the goals of efficiency, effectiveness and cost-effectiveness in the maintenance area and where the overall goal is to contribute to company's profitability and competitiveness (Fig. 1).

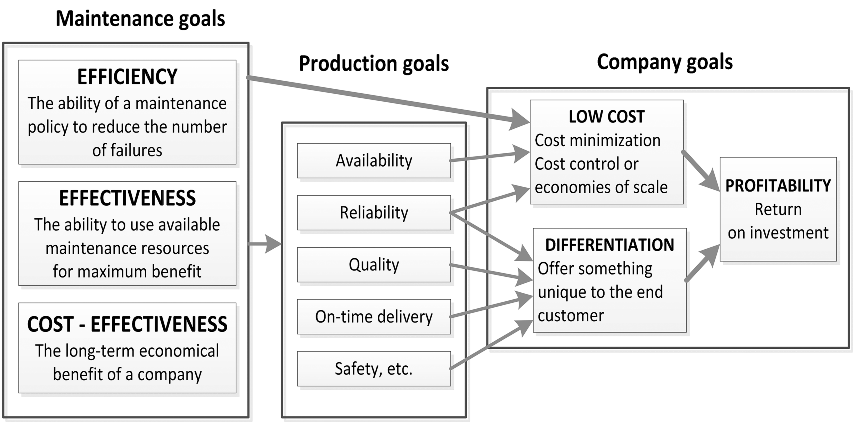

Fig. 1. Connection between maintenance and profitability [27]

Many maintenance strategies have been developed in the last decades and applied to a large array of industries. The interesting classification of maintenance policies is found in [28]. The author describes, from his point of view, the traditional division of maintenance policies into 3 categories: technology oriented (Reliability Centred Maintenance - RCM), human factors oriented (Total Productive Maintenance - TPM) and monitoring and inspection oriented (Condition-Based Maintenance - CBM). The strategies listed above are widely discussed in the literature. However, in the enterprises many "individualized maintenance strategies" refer to "knowledge-based enterprise". The main objective of such methods is to use the immaterial resources of each organization in order to increase the economic benefit resulting from the construction of a maintenance strategy adapted to the requirements and resources of each organization [29].

Looking at maintenance as a profit center rather than a cost center is fundamental to Lean and promotes the idea of investing in maintenance to achieve a future return in production efficiency. However, most companies are solely focusing on manufacturing efficiency by Lean production tools, but a prerequisite for the success of a Lean manufacturer is the concurrent adoption of Lean maintenance [23].

The concept of lean maintenance, which originated in the manufacturing industry, is known as a systematic approach to identify, analyze and eliminate waste through proper management and continuous improvement. Levitt [30] defined lean maintenance as delivery of maintenance services to customers with as little waste as possible. This promotes achievement of a desirable maintenance outcome with fewest inputs possible.

Inputs include labor, spare parts, tools, energy, capital, and management effort. The gains are improved plant reliability (availability) and improved repeatability of process (less variation). Broader definition was formulated by Ricky Smith [31], he defined Lean Maintenance as a “proactive maintenance operation employing planned and scheduled maintenance activities through total productive maintenance (TPM) practices, using maintenance strategies developed through application of reliability centered maintenance (RCM) decision logic and practiced by empowered (self-directed) action teams using the 5S process, weekly Kaizen improvement events, and autonomous maintenance together with multi-skilled, maintenance technician-performed maintenance through the committed use of their work order system and their computer managed maintenance system (CMMS) or enterprise asset management (EAM) system”.

The fundamental concept of Lean maintenance is to reduce all resource needs (inputs) to the lowest possible level consistent with achieving the desired level of equipment reliability (output). To achieve this goal requires removing waste from all processes and activities. Waste is defined as any resource or activity related to the process that is not contributing value to the end “product”, in this case defined as equipment availability. The biggest losses in maintenance, and thus the biggest improvement opportunities include:

– Manufacturing Reliability (loss in quality, stop times, loss in speed);
– Partnership between Operations – Maintenance – Engineering (reliability and maintenance related design, operator based maintenance);
– Elimination of root cause of the problem (choose problem to eliminate; eliminate problems, educate and teach);
– Storage (reduce the store value at the same time as you preserve service level to maintenance);
– Integration and application of increased knowledge and skills (education and training of crafts people to enable multi craft or multi skills);
– Over maintenance (perform too much and wrong preventive maintenance, perform preventive maintenance before it is needed, do corrective maintenance with higher priority than needed);
– Use of new technology (less need for maintenance, better maintainability, smart tools and methods).

Lean Manufacturing can never achieve the best possible attributes of “Lean” without a Lean Maintenance operation. By definition, Lean means quality and value at the least possible cost. Without maximum equipment reliability - a product of optimized Lean maintenance practices - maximum product quality can never be attained. A manufacturing plant with intentions of implementing Lean Manufacturing should begin with a few essential preparations. One of the most important preparations is the configuration of the maintenance organization to facilitate, first - Lean Maintenance, and next - Lean Manufacturing. The Maintenance function needs to implement plans to integrate and evolve its methods to meet the new demands placed on it by Lean Manufacturing. Lean Thinking can help the Maintenance department to deliver improved departmental performance, lasting change and raise the profile of Maintenance as a value adding function rather than a cost. The efforts of Lean will improve the maintenance “product” quality by lowering measurable process outputs (amount of rework, number of maintenance-induced failures, and so on). Identifying the customer and focusing on improving quality and lowering cost of the product are common elements to both maintenance and manufacturing.

4 Lean Maintenance Tools and Its Effectiveness

The Maintenance function needs to implement plans to integrate and evolve its methods to meet the new demands placed on it by Lean Manufacturing. A comprehensive lean tools developed for maintenance activities within an organization include VSM, 5S, overall equipment effectiveness (OEE), Kaizen, work standardization TPM, SMED, computer maintenance managed system (CMMS) [32]. The above-mentioned lean maintenance tools are used in enterprises representing different industries, results of tier implementation are evaluated with metrics and indicators of financial and non-financial character. The examples of the implementation of lean tools into maintenance in three different companies representing food industry are presented below. According to numerous studies, the food industry is, together with the automotive industry the sector in which maintenance process is under particular supervision. It is consequence of the fact that the maintenance of machinery and equipment has a direct impact on the health safety of products.

4.1 Value Stream Mapping - VSM

Value stream mapping has supporting methods that are often used in Lean environments to analyze and design flows at the system level (across multiple processes) [33]. Value stream mapping analyzes both material and information flow. By drawing the VSM, the practitioners were able to: visualize and clearly see the entire flow, identify the waste in the value stream, establish the linkage between the information flow and the material flow and understand how the organization will be in the future, if all the improvement activities are implemented properly and if the identified wastes were eliminated or removed. Although value stream mapping is often associated with manufacturing, it is also used in maintenance. Implementation of the tool to maintenance was introduced, among others, in [34]. The example in the Fig. 2 presents breakdown procedure.

Evaluation of the result of the project was presented by non-financial measures (reduction of time), but in operating conditions of the company that measure has a significant impact on the number of goods produced, and therefore money.

4.2 5S Practices

5S practices are a component of lean maintenance which creates room for standardized environment for work, with a focus on waste elimination and involves five steps. Successful application of 5S may provide the following advantages in maintenance: workplaces more efficient, organized, clean, productive and safe; improvement of

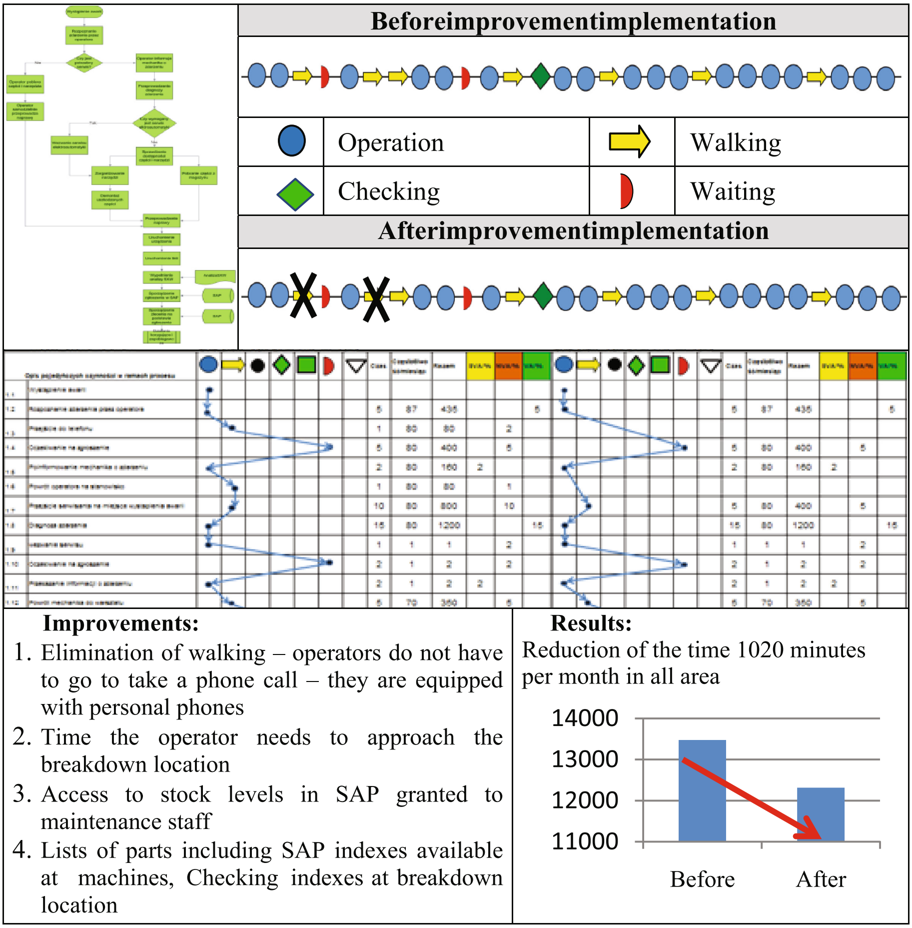

Fig. 2. Value stream mapping - breakdown procedure

working conditions; better view of the problems; reduction of costs, unproductive time, space and movements; and reduction of losses related with failures and breaks.

Introduction of 5S practices into maintenance processes shortens the time of repair (one of the indicators most commonly used to assess the effectiveness of the work of maintenance is MTTR - Mean Time To Repair), which affects the efficiency of production equipment, increasing OEE (Fig. 3).

In the 5S process a key role play visual controls by providing an effective tool to remove clutter and organize the workplace. Visual controls present to the manufacturing operator/maintainer: What the user needs to know; When the user needs to know it: Where the user needs to see it; in a format that is clearly understood by the user. Visual controls are varied and may be specific to a particular production environment. Some examples of visual controls include: graphic visual controls, audio visual controls and automated visual controls.

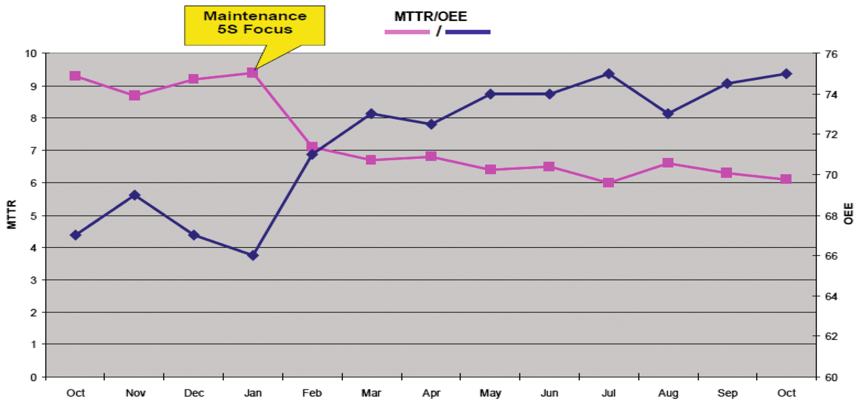

Fig. 3. Relation between MTTR and OEE - example

According to Gupta and Jain [35], 5S is the basic starting tool used to make companies neat and standardized.

4.3 Standardization

For many Lean projects, the key to sustainability is standardization of work technique. The standardized work process is designed for the purpose of providing the technician with the current best method to safely and efficiently perform his or her work, at a target quality level set by the organization. In the food industry standardization of activities carried out by operators (e.g. washing a machine) and maintenance staff (repairs, adjustments, etc.) is of particular importance. Identifying places of accumulation of dirt, eliminating places hard to reach from the perspective of maintaining cleanliness and the process itself are actions that reduce the possibility of contamination of the product in its manufacturing process. In companies that benefit from TPM practices within Autonomous Maintenance pillar teams of operators and maintenance staff identify possible places of accumulation of dirt, places difficult to reach and develop standards for cleaning and washing. These standards are the most commonly known under the name One Point Lesson - OPL. Sample procedure shown in Fig. 4.

Lean maintenance activities are only as effective as their sustainability. This implies the need to establish goals, analyze trends and take actions adequate to the situation. Identifying the need to develop OPL is one thing, another, no less important is the content of OPL - how to perform the work contained in the document. A commonly used tool is the PDCA cycle (Deming cycle), which not only systematizes actions of teams working on the reduction of losses and the definition of standards, but also draws attention to the fact that the standard to be effective must lead to repeatable results, regardless of which of employees will use it. Hence the need for trend analysis and the definition of the moment in which sustainability has been reached. An example of an analysis of the effectiveness of measures taken by the AM team towards definition of the standards of cleaning machines in one of the food industry representatives is shown in Fig. 5.

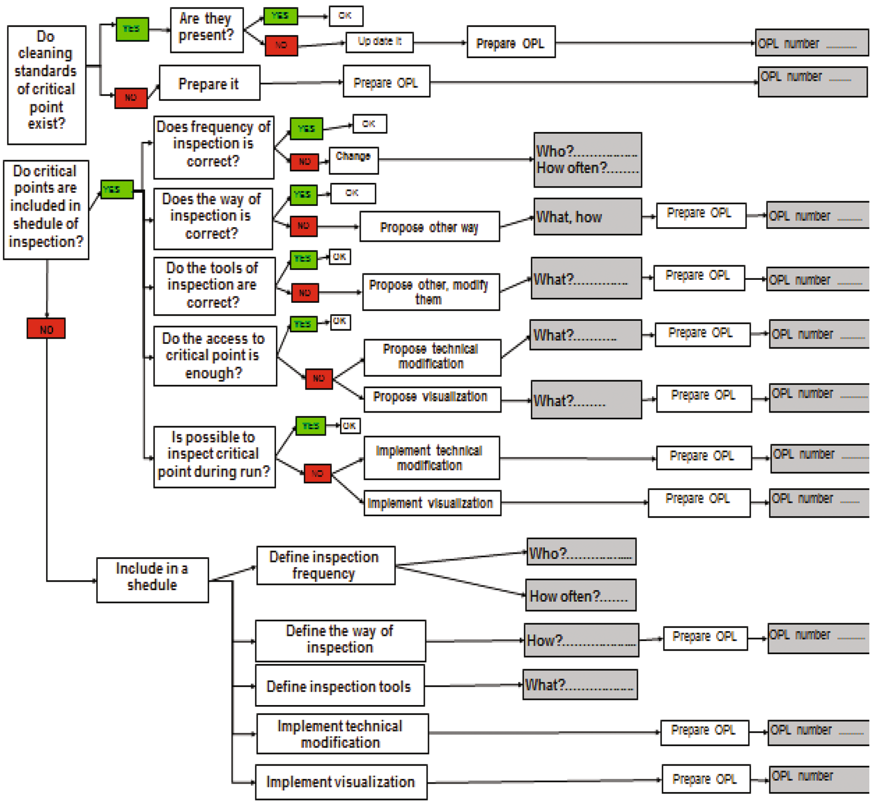

Fig. 4. Critical point analysis sheet - example

Analysis of the trend enables assessment of not only the effectiveness of the actions taken (the goal was to reduce the cleaning time for the machine) but sustainability of results in the longer term. If the effect is maintained over a longer period of time (this time is determined by the team at the planning stage) then the method of implementation can be documented in the form of OPL.

4.4 Total Productive Maintenance

A very foundation of Lean Maintenance is Total Productive Maintenance (TPM). TPM is an initiative for optimizing the reliability and effectiveness of manufacturing equipment. TPM is team-based, proactive maintenance and involves every level and function in the organization, from top executives to the shop floor [5]. TPM addresses the entire production system life cycle and builds a solid, shop-floor-based system to prevent all losses. TPM objectives include the elimination of all accidents, defects and breakdowns. One of the most important pillar of TPM concept is “Autonomous maintenance”. This pillar includes the following issues: team work (operator, mechanic

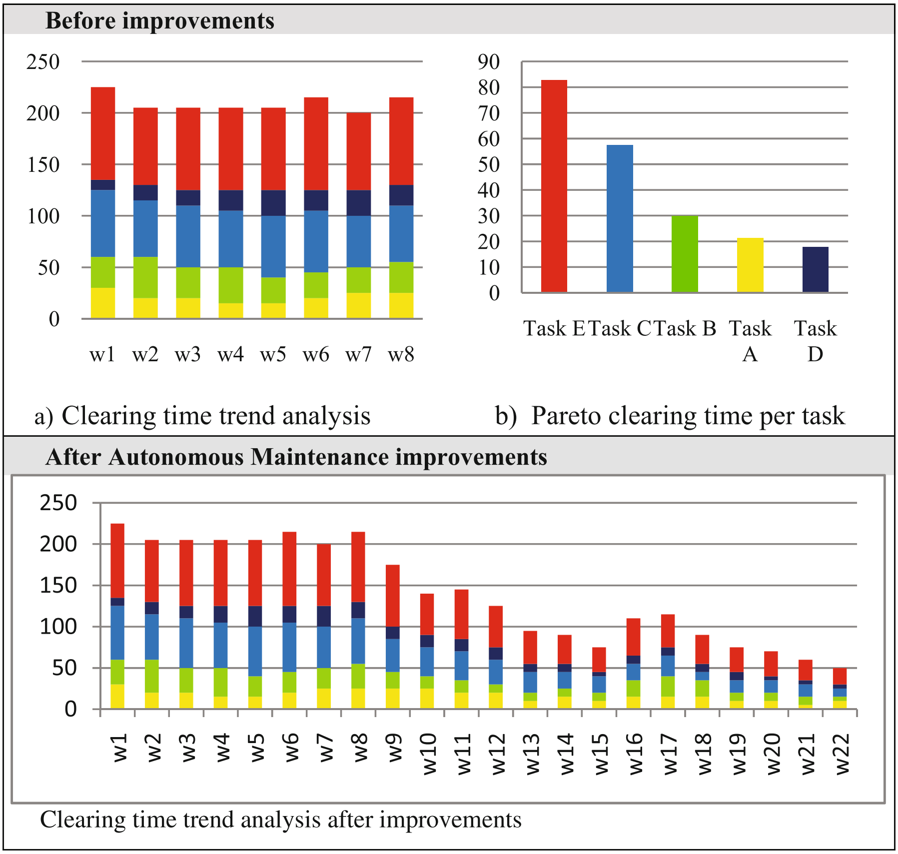

Fig. 5. Clearing time trend analysis before and after improvements

and electrician together take care for machines and other devices to produce high quality products at reasonable costs), bringing optimal work conditions back (installations without defects, easily conservable, clean, operating according to technological and quality specifications), maintain optimal work conditions (systematic inspections, cleaning, planned lubrications). As a result of involving employees in improvement action, a system of initiatives development "Kaizen" is developed. To be successful "Kaizen" requires good leadership, careful planning and good performance measurement system. The measurement of performance is important for both teams of employees who design and implement improvement actions and for managers. The effectiveness of work of teams can be assessed using both measures of financial and non-financial character. An example of such evaluation is shown in the Fig. 6.

The form described above enables the assessment of effectiveness of individual teams involved in activities to improve the maintenance processes. Any action taken by a team is associated with resources and can be treated as a form of investment. Thus, the assessment of these activities from the perspective of ROI is justified.

	Theoretic Performance	Before team	After team	Change	PLN / year	Financial Factor	
Potential benefit	**A** - Stock value (euro)					Carrying cost %	....
	B - Stock Turnover						
	C - Material Expenses (euro/year)					direct impact	....
	D - Service expenses (euro/year)					direct impact	....
	E - Total task time (man-hours / year)					hour rate maintenance	....
	F - Planned downtime (Hour/year)					planned down cost	....
	G - Breakdown time (Hour/year)					unplanned down cost	....
Cost:	Man-hours used in team					hour rate team members	....
Return On Investment = $\frac{\cdots\cdots}{\cdots\cdots}$							

Fig. 6. The effectiveness of work of teams evaluation - example

5 Conclusion

Nowadays every company aims to increase, or at least sustain, their profitability by controlling and reducing production costs. The Maintenance department and maintenance service it provides don't exist in isolation to the rest of the business – it is part of a system. Maintenance activity is a fundamental pillar sustaining product high standards and plant availability. Without this viewpoint, the maintenance results remain restricted to the performance of each action, losing the overall perspective.

Maintenance influences and is influenced by Lean Manufacturing. The impact of Maintenance on Lean Manufacturing is its ability to improve the value adding capability by delivering: (1) stabilized performance to reduce unplanned events and waste and (2) optimized performance to reduce quality defects, cost and delivery lead times. The Impact of Lean Thinking on Maintenance is its tools to guide the reduction of waste and non-value added maintenance activities i.e. stabilize and extend component life by controlling contamination and minimizing human error; analyze and remove unnecessary maintenance procedures; developing standard countermeasures to common problems; reduce time to repair; engage operators in asset care and improve ease of inspection and early problem detection.

References

1. Pakdil, F., Leonard, K.M.: Criteria for a lean organization: development of a lean assessment tool. Int. J. Prod. Res. **52**(15), 4587–4607 (2014)
2. Burduk, A., Musiał, K.: Optimization of chosen transport task by using generic algorithms. In: Conference on Computer Information Systems and Industrial Management (CISIM). LNCS, vol. 9842, pp. 197–205 (2016)

3. Dostatni, E., Diakun, J., Grajewski, D., et al.: Multi-agent system to support decision-making process in design for recycling. Soft Comput. **20**(11), 4347–4361 (2016)
4. Kłosowski, G., Gola, A.: Risk-based estimation of manufacturing order costs with artificial intelligence. In: Ganzha, M., Maciaszek, L., Paprzycki, M. (eds.) Proceedings of the 206 Federated Conference on Computer Science and Information Systems (FEDCSIS), pp. 729–732. IEEE (2016)
5. Lewandowska, A., Więcek-Janka, E.: European version of a balanced scorecard in family enterprises (own research). In: 3rd International Conference on Management Science and Management Innovation (MSMI 2016), pp. 219–223. Atlantis Press (2016)
6. Kałkowska, J.: Information and communication technologies supporting fuzzy knowledge management. In: Schlick, Ch., Trzcieliński, S. (eds.) Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future, Proceedings of the AHFE 2016 International Conference on Human Aspects of Advanced Manufacturing, Walt Disney World®, Florida, USA, pp. 363–374. Springer International, 27–31 July 2016
7. Gabryelewicz, I., Sadłowska-Wrzesińska, J., Kowal, E.: Evaluation of safety climate level in a production facility. In: Procedia Manufacturing: 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015. Procedia Manufacturing, vol. 3, pp. 6211–6218. Elsevier B.V. (2015)
8. Burduk, A.: Assessment of risk in a production system with the use of the FMEA analysis and linguistic variables. In: Hybrid Artificial Intelligent Systems: 7th International Conference, HAIS 2012. LNCS, vol. 7209, pp. 250–258 (2012)
9. Włodarkiewicz-Klimek, H.: The analysis and assessment of the degree adaptation of human capital in polish enterprises' to the knowledge-based economy requirements. In: IFKAD 2015 – 10th International Forum on Knowledge Asset Dynamics, Culture, Innovation end Entrepreneurship: Connecting the Knowledge Dots, pp. 143–154 (2015)
10. Krenczyk, D., Skolud, B.: Transient states of cyclic production planning and control. Appl. Mech. Mater. **657**, 961–965 (2014)
11. Fraser, K.: Facilities management: the strategic selection of a maintenance system. J. Facil. Manag. **12**, 18–37 (2014)
12. Mazurkiewicz, D.: Maintenance of belt conveyors using an expert system based on fuzzy logic. Arch. Civ. Mech. Eng. **15**(2), 412–418 (2015)
13. Pinjala, S.K., Pintelon, L., Vereecke, A.: An empirical investigation on the relationship between business and maintenance strategies. J. Prod. Econ. **104**, 214–229 (2006)
14. Loska, A.: Scenario modeling exploitation decision-making process in technical network systems. Eksploatacja I Niezawodnosc – Maintenance Reliab. **19**(2), 268–278 (2017)
15. Shah, R., Ward, P.T.: Defining and developing measures of lean production. J. Oper. Manag. **25**(4), 785–805 (2007)
16. Womack, J.P., Jones, D.T.: Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Simon & Schuster, New York (1996)
17. Shah, R., Ward, P.T.: Lean manufacturing: context, practice bundles, and performance. J. Oper. Manag. **21**, 129–149 (2003)
18. Ohno, T.: Toyota Production System: Beyond Large Scale Production. Productivity Press, Portland (1988)
19. Antosz, K., Stadnicka, D.: The results of the study concerning the identification of the activities realized in the management of the technical infrastructure in large enterprises. Eksploatacja I Niezawodnosc - Maintenance Reliab. **16**(1), 112–119 (2014)
20. Sullivan, W.G., McDonald, T.N., Van Aken, E.M.: Equipment replacement decisions and lean manufacturing. Robot. Comput. Integr. Manuf. **18**, 255–265 (2002)
21. Zwas, A.: Lean manufacturing techniques in bus and rail maintenance: study at Chicago transit authority in Illinois. J. Transp. Res. Board **1986**, 54–58 (2006)

22. Kujawińska, A., Vogt, K., Hamrol, A.: The role of human motivation in quality inspection of production processes. Advances in Intelligent Systems and Computing, vol. 490, pp. 569–579 (2016). HAAMAHA
23. Baluch, N., Abdullah, C.S., Mohtar, S.: TPM and LEAN Maintenance - a critical review. Interdisc. J. Contemp. Res. Bus. **4**(2), 850–857 (2012)
24. Antosz, K., Ratnayake, Chandima, R.R.M.: Machinery classification and prioritization: empirical models and AHP based approach for effective preventive maintenance. In: IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bali, Indonesia, pp. 1380–1386, 4–7 December 2016
25. Khairy, A., Kobbacy, H., Prabhakar Murthy, D.N.: Complex System Maintenance Handbook. Springer Series in Reliability Engineering. Springer, London (2008)
26. Márquez, A.C., Gupta, J.N.D.: Contemporary maintenance management: process, framework and supporting pillars. Omega **34**, 313–326 (2006)
27. Kans, M.: On the utilization of information technology for the management of profitable maintenance (Ph.D. Dissertation) Sweden, p. 23. Växjö University Press, Acta Wexionensia (2008). http://www.diva-portal.org/smash/get/diva2:205901/FULLTEXT01.pdf
28. Labib, A.: A decision analysis model for maintenance policy selection using a CMMS. J. Qual. Maintenance Eng. **10**(3), 191–202 (2004)
29. Hogan, J., Hardiman, F., Daragh Naughton, M.: Asset management: a review of contemporary & individualised strategies. In: Proceedings of the World Congress on Engineering, vol. I, WCE London, U.K. (2011). http://www.iaeng.org/publication/WCE2011/WCE2011_pp545–549.pdf
30. Levitt, J.: Lean Maintenance. Elsevier Butterworth-Heinemann (2008)
31. Smith, R.: What is Lean maintenance? Elements that need to be in place for success. Maintenance Technol. Mag. **17**, 15–21 (2004). http://www.mt-online.com/article/1004smith. Accessed 28 Apr 2016
32. Mostafa, S., Dumrak, J., Soltan, H.: Lean maintenance roadmap. In: 2nd International Materials, Industrial, and Manufacturing Engineering Conference, MIMEC 2015. Procedia Manufacturing, vol. 2, Bali, Indonesia, pp. 434–444, 4–6 February 2015
33. Waszkowski, R., Nowicki, T., Saniuk, A.: Human-computer interaction in sanitary inspection simulation exercises. In: Soares, M., Falcão, C., Ahram, T. (eds.) Advances in Ergonomics Modeling, Usability & Special Populations: Proceedings of the AHFE 2016 International Conference on Ergonomics Modeling, Usability & Special Populations, Walt Disney World®, Florida, USA, pp. 245–254, 27–31 July 2016
34. Pogačnik, B., Tavčar, J., Duhovnik, J.: Application of lean methods into aircraft maintenance processes. In: Curran, R., et al. (eds.) Transdisciplinary Lifecycle Analysis of Systems, pp. 259–268. IOS Press (2015)
35. Gupta, S., Jain, S.K.: A literature review of lean manufacturing. Int. J. Manag. Sci. Eng. Manag. **8**(4), 241–249 (2013)

One Point Lesson as a Tool for Work Standardization and Optimization - Case Study

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Abstract. The usage of single-point lessons is a technical support for machine operators. The lessons are one-page instructions, complementing the knowledge with diagram of described main or sub-process. They are operating instructions, whose task is to guarantee repeatability of performed actions, and deliver the basic knowledge to operators, equalize it and teach best possible solutions. The instructions determine the method of actions to solve the problem in best known way. Their short content and diagram or photo included make agreed way of working easier to remember. They indicate stability and continuity of the process, share the knowledge of advanced operators in the form of single page instructions.

Keywords: Standardization · Lean manufacturing · One point lesson · Technical procedure · Lacquering UV line · Lacquering process

1 Introduction

Contemporary machines grouping in mutually dependent technological strings obliges companies to new interpretation of tasks to technical system [1, 2]. Organizing and automation of work, previously done intuitively or inadvertently, are used to determine process standards, operation times, identification and elimination of waiting, downtime, replicates and unnecessarily performed activities [3–5]. This inter-organizational activities, which consists of documents preparation for activities repeatability regulation, operations and processes, is designed to ensure maximum efficiency, reducing waste and increasing competitiveness [6–11]. Issues related to work standardization in modern technology parks refer to efficiency improvement of operations by minimizing or complete elimination of waste, and controlling the flow of the added value of lean production Lean Manufacturing (LM) [12]. The wastage of Lean, defined as *Muda*, refers to the eight types of losses: overproduction, waiting, unnecessary transport, excessive or incorrect processing, excess inventory, unnecessary motion, defects, not used employees creativity [13]. The keynote in the LM is proper processes designing, which minimizes waste not recognized in planning and organizing before [14–16].

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The article is to discuss issues related to the unification of activities undertaken in the course of handling a roller coating UV lacquering line, through the use of One Point Lesson OPL cards. The paper attempts to analyze activities taken on preparation for work and setting up roller line to a given process suggested by the lacquers supplier. The discrepancy in setting the line parameter, can lead to insufficient curing of the lacquer by the UV lamps risking that the product will lose its surface resistance parameters.

2 The Concept of Standardization in Lean - Historical Outline

The concepts of work organization and standardization were initiated by American engineer Frederick Taylor. In his management model encouraged the strict determination of labor standards, employee tasks and organization of workplace. Taylorism, although reluctantly accepted by the workers themselves, understands the concept as a way to increase the exploitation of workers, has been used by plants to Ford automobiles factories. The work, based on the idea of Ford was continued in 50s of the twentieth century in Japan by Koichi Shimokawa and Takahiro Fujmoto. The idea of the Toyota's factory car production system, based on the movable lines working in smooth synchrony, improving the concept under the influence of epochal paradigm change for Comprehensive Control of Quality (Total Quality Control-TQC) [16]. The name of Lean Management was used by J.F. Krafcik in 1988, followed by Womack, Jones and Roos, in "Machine that changed the World" [17], popularizing the ideas of Japanese management concept in the global market. LM overriding goal is to eliminate waste, that is, everything that raises production costs without paying for it a useful contribution and commitment to eliminate losses through activities and behavior standardization in the manufacturing process acting enormous potential source of corporate performance and customer service improvement. [18] The basic tools of LM concept, among others [19–22] are: the practice of 5S, Kaizen, SMED, VSM, OPL-one point lesson, TPM, Kanban, JinT-Just in Time.

The modern routine tasks production model refers to all aspects of the work relating to: the allocation process elements to the operation sequence and methods for their exercise in space and time, the cast, the number of required resources and the processed objects (inventory) and other important elements affecting the progress and results of the work and performance monitoring [23–28].

3 Interpretation of Standardization in Manufacturing Companies

Standardization can be defined as the process of creating and applying the rules, aiming to organize specific activities for the benefit and cooperation interested sides. It involves: rational selection, ordering, simplification and unification of symbols, concepts, types, sizes, shapes, physical and chemical properties, methods of research, methods and accuracy of processing and delivery conditions of product. This includes standardization planning, development and standard setting, putting them into force, implementation effects examination and control of their application. Based on the above, it can be assumed that the standard is a static concept, defining a state, and standardization is a dynamic concept, defining the performance of something in a reproducible manner.

Another interpretation of the concept says that the work processes is needed to facilitate efficient, safe work methods and eliminate wastes, while maintaining quality [29]. Lean standardization refers to the process in the safest and easiest way for the employee, and the most cost-effective and productive for the company and to guarantee the quality for the customer [30]. Standardization as a continuation of normalization activities carried out at the level of the organization, through the introduction of documents regulating individual activities, their exact descriptions, to unify the proceedings and easy replacement of the employee, if necessary.

In order to disseminate the standards, enterprises expose necessary documentation at workstations, as an extension and clarification of organizations decisions.

The currently popular instruction can be classified as One Point Lessons (OPL). These are simple documents, usually framed with foil and attached in a visible place on the machine (the area parameter change or significantly affecting expected results to the product), or for information on the place of performance of the activity. These instructions, usually created based on the knowledge of operators are the most effective actions and form the basis for repeatability course of action on one object by employees of different changes.

The use of single sided support cards should always be based on the knowledge of people directly related to the subject and their excess can cause discouragement employee to work. It is recommended to make sure that the instruction is actually needed in the workplace and also to be aware of certain restrictions on the company, leading to work stoppages as a result of over-exploitation of the worker or object. However, the instructions are helpful in better understanding the process, its stable flow and safe behavior in the workplace.

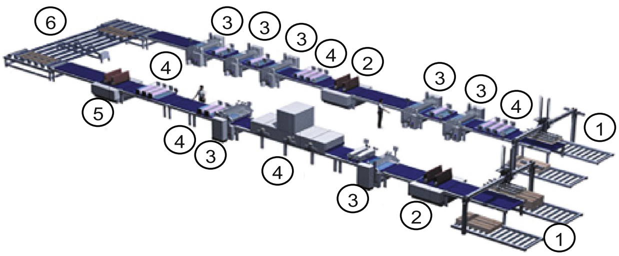
4 Interpretation of One Point Lessons in Enterprise

4.1 Object Characteristics – Roller Coating UV Line

The object of observation of the process is a roller coating UV line designed for furniture flat elements treatment. The process is cyclical lacquer layer film application on furniture elements, which in appropriate conditions (with UV-light) forms a solid coating bonded to the substrate with defined mechanical, protective and decorative function. Example of a line roller shown in Fig. 1.

4.2 Roller Coater

The roller coater is a device equipped with dosing roller, blurring roller, carrying roller, doctor blades, pump, gutters and guards. Staining of the items takes place according to the diagram (Fig. 2):



1. Feeder and stacker.
2. Sanding units
3. Roller coaters (lacquer application)
4. Drying tunnel, UV lamps
5. Brushing machine
6. Conveyors

Fig. 1. Example of roller coating UV line.

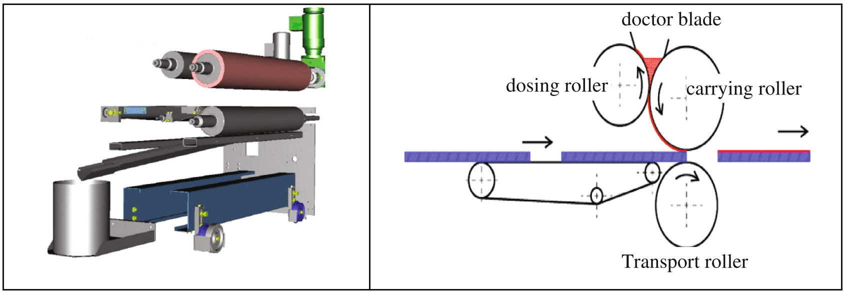


Fig. 2. Roller coater scheme

- metal dosing roller regulates the amount of the applied lacquering layer,
- doctor blade removes excess of applied material and distributes coating evenly and cares for cylinder cleanliness,
- carrying roller, made of rubber, whose hardness is determined in units of Shore (° ShA) for direct application on treated element.

4.3 Process Card

Roller coating UV line consists of multiple machines connected together. For workers of quality control, office workers or lean specialists the knowledge of technology is enough. Each of them will give priority to different technological aspects. For example, quality controller will check whether the amount of material being applied is consistent with the technological parameters, and office worker check if line operator wares hearing protector. To the Board important roles are the costs of used materials and compliance with the quality demands to the product. An example of a technological process for the line is shown in Fig. 3.

On the basis of the information contained in Fig. 3, the process indicates the basic parameters, but different methods of work can be easily use, what does not break lacquer supplier guidelines. The interval from-to, is dictated by the influence of the environment on the process (temperature outside and inside, humidity, day time or day of the week, materials wear, sanding, UV lamps effectiveness, etc.), as well as the same

Customer/Customer No.	**XYZ**
Program	**001**
Substrate material	BoF
Color tone/gloss level	white : 90/ +5-5
Designation of the production plan/plant plan	UV Line ALA from 20.11.2016

Important remarks	UV system for flat line
Feed rate/cycle time	19m/min
Stackable/packable	yes

No.	Finishing stage/product	Parameters/product/notes	Application g/m²
1	Straight transport	transport belt	
2	Sanding	P.: 280 +320	
3	Sanding with flap sander	One brush P. 320	
4	Roller application with smooth roller, 40 Shore	XX1	12-15g/m²
5	Curing by UV module Hg 80 W/cm²	80%:UV A: 100-120mJ/cm² and 160-180mW/cm²	
6	Transport		
7	Roller application with smooth roller,40 Shore	XX1	12-15g/m²
8	Curing by UV module Hg 80 W/cm²	80%:UV A: 100-120mJ/cm² and 160-180mW/cm²	
9	Curing by UV module Hg 80 W/cm²	100%:UV A: 150-180mJ/cm² and 180-220mW/cm²	
10	Sanding	P.: 280 +320	
11	...		
15	Roller application with smooth roller,40 Shore	XX2	10-15g/m²
...			

Fig. 3. Treatment technology for flat surfaces

quality of element surface to factors such as quality grade, number previously applied layers on the substrate (raw elements or if element are lacquered again to repair the surface). A substantial impact on the lacquers consumption is the line automation. At high speeds, the occurrence of deviations from set parameters are counted in the number of pallets rather than individual pieces. In general, the detail and easier treatment process is described that is easier to control application of lacquer to maintain the desired quality of the product.

4.4 Elimination of Waste

Modern manufacturing plants in its parks can have a quick and automated lacquering lines. Consumption of lacquer on one object can be 15−20 thousands kilograms per month, putting the company on a number of losses and the risk associated with the complaint or total loss of the product. From the perspective of a single operator, working not according to the procedure should not have major consequences. However, based on statistical data purchase costs of additional lacquers are huge and sometimes the same manufacturer fulfilling orders in accordance with the schedule is not able to provide additional lacquers if they are missing in factory due to overconsumption. UV lacquers have their expiry date and their cost is so big that production to build a stock is unprofitable. Of course, for the sake of cooperation, such situations occur but in the best case production is expected for delivery the additional lacquer a couple of hours. From perspective of situation described above, the evaluation of consumed materials and their deviations from the desired technology in the context of total consumption shows Table 1.

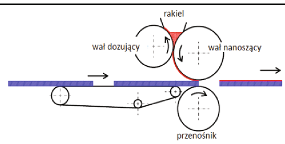
Table 1. Overconsumption of lacquering materials due to diviation to agreed parameters

Period:	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Line A	17%	15%	27%	21%	22%	18%	24%	15%	19%	17%	19%
Line B	34%	21%	32%	38%	39%	21%	26%	31%	25%	24%	28%
Line C	14%	12%	11%	35%	15%	11%	14%	16%	16%	12%	11%

According to the analyzed case corrective action should be taken and additional standardization process in order to search for the root causes of the condition should be made. The interesting thing was that the records in the control books did not differ to preset standards and any deviation as a result of the inspection was immediately corrected. It also turned out that each operator has its own way of working and it is difficult to determine which one is the best. Therefore, it was decided make a meeting where proposed a game that allowed to search together best work schemes. Invited operators were making paper airplanes and then tried to direct them into the container. Operators improving and perfecting construction of their paper machines, while improving their efficiency in flight. This apparent game helped to understand how each of them strives to achieve the production process while maintaining quality for the product. It turned out that one-page manual should be prepared, on the basis of which they perform certain standard tasks that are repetitive and at the same time that they are not exposed. Example of such instructions are shown in Figs. 4 and 5.

Preparation of cards explaining how to set the machine showed what derogation from the assumptions can be used. In addition, operators have developed a list of the best standards to operate machines. It turned out that the overall process itself does not guarantee stability of lines work and prepared information helped in better understanding. Assessment of operator's work on the basis of publicly available data not always shows the enormity of the tasks of processing line. Creating one point lessons so far focused on the 5S in the production were the breakthrough in interpretation of previously user system instructions. The company has established a common language

Company name (logo)	ONE POINT LESSON – OPL **Registered document**				
Instruction name: Rollers marking	Area: Lacquering dep.	Doc. No.	Date:	Actualisation date:	Version:
	Workstation: Linia X		Owner:		



Roller coater setup parameters

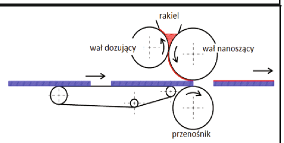
Roller coated transport speed (m/min)	35-38
Dosing roller speed (m/min)	8,3-9,8
Carving roller speed (m/min)	34-36
Dosing roller teperature (°C)	15-18
Carving roller temperature (°C)	22-25
X-material application before carving (g/m²)	40-44
X-material application after carving (g/m²)	25-28
X-material temperature (°C)	24

Safety symbol:		Signatures: Shift A Shift B Shift C Shift D	Foreman:	Operator:

Company name (logo)	ONE POINT LESSON – OPL **Registered document**				
Instruction name: Rollers marking	Area: Lacquering dep.	Doc. No.	Date:	Actualisation date:	Version:
	Workstation: Linia X		Owner:		

Distance between rollers setup

Distance between rollers	Lacquer application before carving (g/m²)	Lacquer application after carving (g/m²)
00030	65	18-20
00027	50	18-20
00024	40	18-20
00021	35	18-20
00018	30	18-20



Safety symbol:		Signatures: Shift A Shift B Shift C	Foreman:	Operator:

Fig. 4. One point lessons

that is understandable to a larger group of people. As a result of new working schemes for line parameters setup subsequent measured time periods showed lower lacquering materials consumption, as shown in the graph in Fig. 6.

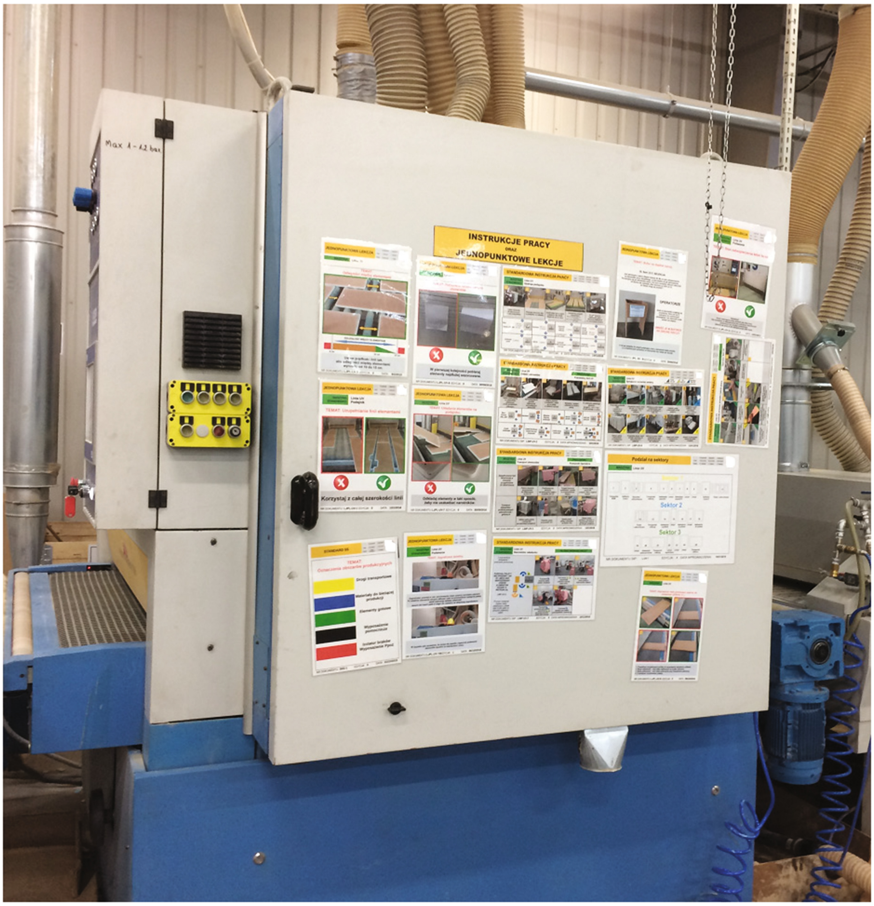


Fig. 5. One point lessons with exposition on workstation.

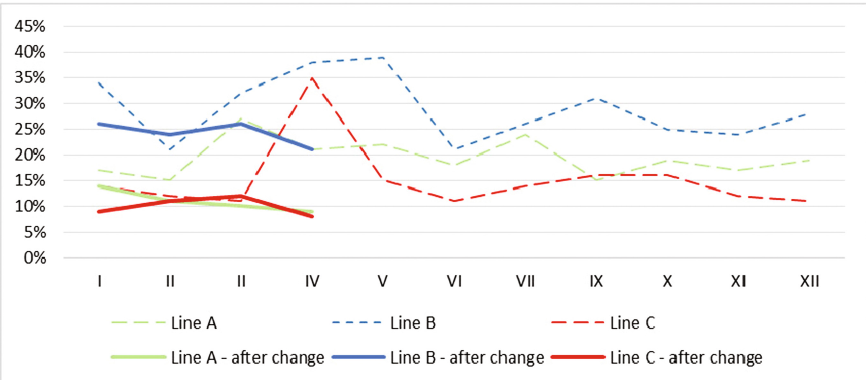


Fig. 6. Assessment of situation after OPL implementation.

5 Conclusion

The task of lines operation unification was also to develop a method of common working method at each shift and applied by all operators working with the line. The advantage of One Point Lesson is transparency and complete knowledge of the specific technical parameters, which up to now were knowledge of people directly associated with the line. Additional information, including how to get the machine to work, located at every crucial point of the activities undertaken by operators, added to the knowledge of people associated with the technical aspects of the operation. At the same time it facilitated the work of new employees who can operate the machine obtaining the same results as experienced operators from another shift. In case the process change, employee uses all information gathered in the designated place on the line and may proceed in accordance with the new scheme. These activities allowed for a more complete standardization and work efficiency increase of lacquering line, providing the same quality background for manufactured products. As a result, it has improved safety, as operators stopped the use of additional activities that were raising the risk related to the accident as a result of roller coaters operating, limiting it to work according to accepted patterns. Additional benefit for the company was reduction of consumed lacquers amount by 19%, which contributed to a reduction manufactured products unit cost. Amount of ordered lacquered materials that were ordered on the basis of proposed by the supplier of lacquering technology without the risk of stopping production in the absence of materials for elements treatment were reduced, too.

References

1. Burduk, A.: Artificial neural networks as tools for controlling production system and ensuring their stability. In: 12th IFIP TC8 International Conference on Computer Information Systems and Industrial Management, CISIM 2013. LNCS, vol. 8104, pp. 487–498. Springer (2013)
2. Stadnicka, D., Chandima, R.R.M,. Antosz, K.: Investigation of process approach implementation in manufacturing firms: a methodology for assessing process excellence level. In: 2015 IEEE International Conference on Industrial Engineering and Engineering Management, IEEM, Singapore, Singapore, 06–09 December 2015, pp. 159–164. IEEE (2015)
3. Juszczynski, M., Kowalski, A.: Achieving desired cycle times by modelling production systems. In: Saeed, K., Chaki, R., Cortesi, A. et al. (eds.) 12th IFIP TC8 International Conference on Computer Information Systems and Industrial Management Applications (CISIM 2013), Krakow, Poland, 25–27 September 2013. LNCS, vol. 8104, pp. 476–486 (2013)
4. Kosicka, E., Kozłowski, E., Mazukiewicz, D.: The use of stationary tests for analysis of monitored residual processes. Eksploatacja i Niezawodnosc – Maint. Reliab. **17**(4), 604–609 (2015)
5. Pawlowski, K., Pawlowski, E.: Modern manufacturing practices and agile enterprise. Anticipated scope of implementation and empirical results from Polish enterprises. In: Ahram, T., Karwowski, W., Schmorrow, D. (eds.) 6th International Conference on Applied

Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, pp. 464–471 (2015)
6. Kujawińska, A., Vogt, K.: Human factors in visual control. Manage. Prod. Eng. Rev. **6**(2), 25–31 (2015)
7. Burduk, A., Jagodziński, M.: Assessment of production system stability with the use of the FMEA analysis and simulation models. In: 16th International Conference on Intelligent Data Engineering and Automated Learning - IDEAL 2015, Wroclaw, Poland, 14–16 October 2015. LNCS, vol. 9375, pp. 216–223. Springer Cop. (2015)
8. Kłosowski, G., Gola, A., Świć, A.: Application of fuzzy logic in assigning workers to production tasks. In: Omatu, S., Selamat, A., Bocewicz, G., Sitek, P., Nielsen, I., Garcia-Garcia, J.A., Bajo, J. (eds.) 13th International Conference on Distributed Computing and Artificial Intelligence. Advances in Intelligent Systems and Computing, vol. 474, pp. 505–513 (2016)
9. Jasiulewicz-Kaczmarek, M., Drożyner, P.: Maintenance management initiatives towards achieving sustainable development. In: Golinska, P. et al. (eds.) Information Technologies in Environmental Engineering Environmental Science and Engineering, pp. 707–721. Springer, Heidelberg (2011)
10. Dinis-Carvalho, J., Ratnayake, R.M.C., Stadnicka, D., Sousa, R.M., Isoherranen, J.V., Kumar, M.: Performance enhancing in the manufacturing industry: an improvement kata application. In: IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bali, Indonesia, 04–07 December 2016, pp. 1250–1254. IEEE (2016)
11. Saniuk, A., Saniuk, S., Jasiulewicz-Kaczmarek, M.: Benefits of KPI implementation in metallurgical enterprises. In: 25th Anniversary International Conference on Metallurgy and Materials (METAL 2016), Brno, Czech Republic, 25–27 May 2016, pp. 2001–2006 (2016)
12. Shah, R., Ward, P.T.: Defining and developing measures of lean production. J. Oper. Manage. **25**(4), 785–805 (2007)
13. Liker, J.K.: Toyota Way: 14 Management Principles from the World's Geatest Manufacturer. McGraw-Hill Education, New York (2004)
14. Jasiulewicz-Kaczmarek, M.: Integrating lean and green paradigms in maintenance management. In: Boje, E., Xia, X. (eds.) Proceedings of the 19th IFAC World Congress Cape Town, South Africa, 24–29 August 2014, pp. 4471–4476 (2014)
15. Womack, J.P., Jones, D.T.: Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Simon & Schuster, New York (1996)
16. Shimokawa, K., Fujimoto, T.: The Birth of Lean. Lean Enterprise Institute, Inc. (2009)
17. Womack, J.P., Roos, D.J.: The Machine that Changed the World. Rawson Associates, New York (1990)
18. Starzyńska, B., Hamrol, A.: Excellence toolbox: decision support system for quality tools and techniques selection and application. Total Qual. Manage. Bus. Excellence **24**(5), 577–595 (2013)
19. Grzybowska, K., Gajdzik, B.: Optimisation of equipment setup processes in enterprises. J. Metalurgija **51**(4), 563–566 (2012)
20. Jasiulewicz-Kaczmarek, M., Drożyner, P.: Preventive and pro-active ergonomics influence on maintenance excellence level. In: Robertson, M.M. (ed.) Ergonomics and Health Aspects, HCII 2011. LNCS, vol. 6779, pp. 49–58. Springer, Heidelberg (2011)
21. Domingos, B.S.M., Ribeiro, R.B., de Barros, J.G.M., de Araújo Júnior, A.H., Sabbadini, F. S.: Process improvement and reorganization of kanban inventory in an industry of machinery and equipment: a case study. J. Mech. Eng. Autom. **4**(2), 49–54 (2014)
22. Brah, S.A., Chong, W.K.: Relationship between total productive maintenance and performance. Int. J. Prod. Res. **42**(12), 2383–2401 (2004)

23. Butlewski, M., Jasiulewicz-Kaczmarek, M., Misztal, A., Sławińska, M.: Design methods of reducing human error in practice. In: Proceedings of the European Safety and Reliability Conference on Safety and Reliability: Methodology and Applications, ESREL, pp. 1101–1106 (2015)
24. Kałkowska, J.: Information and communication technologies supporting fuzzy knowledge management. In: Schlick, C., Trzcieliński, S. (eds.) Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future, Proceedings of the AHFE 2016 International Conference on Human Aspects of Advanced Manufacturing, Walt Disney World®, Florida, USA, 27–31 July 2016, pp. 363–374. Springer International Publishing (2016)
25. Kowalski, A., Marut, T.: Hybrid methods aiding organisational and technological production preparation using simulation models of nonlinear production systems. In: Corchado, E., Snasel, V., Abraham, A. et al. (eds.) 7th International Conference on Hybrid Artificial Intelligent Systems (HAIS), Salamanca, Spain, 28–30 March 2012. LNCS, vol. 7209, pp. 259–266 (2012)
26. Więcek-Janka, E., Mierzwiak, R., Kijewska, J.: Competencies' model in the succession process of family firms with the use of grey clustering analysis. J. Grey Syst. **28**(2), 121–131 (2016)
27. Jasiulewicz-Kaczmarek, M.: Socio-technical integrity in maintenance activities, In: Vink, P. (ed.) Advances in Social and Organizational Factors 2012, pp. 582–592. CRC Press (2012)
28. Stachowiak, A.: Availability and reliability of resources in an agile manufacturing systems. In: Nowakowski, T. et al. (eds.) Proceedings of the European Safety and Reliability Conference (ESREL), Wroclaw, Poland, 14–18 September 2014, pp. 2425–2432 (2015). Sponsor(s): Wroclaw Univ Technol; Polish Safety & Reliabil As-soc; European Safety & Reliabil Assoc Safety and Reliability: Methodology and Applications
29. Dave, Y.: Benefits of standardized work: a study. Int. J. Latest Res. Sci. Technol. **1**(1), 95–97 (2012). MNK Publication
30. Imai, M.: Gemba Kaizen: A Commonsense Approach to a Continuous Improvement Strategy. McGraw-Hill Education - Europe, United States (2012)

Implementation of TPM Methodology in Worker Fatigue Management - A Macroergonomic Approach

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Abstract. The article describes the use of TPM pillars: Focused Improvement, Autonomous Maintenance, Planned Maintenance, Quality Maintenance, Early Equipment Management and Training and Education, along with their implementation for the purposes of fatigue management. Among the various techniques used as part of TPM, the techniques that allow better control over the welfare and safety of workers are highlighted. The following methods proved particularly useful in fatigue management: Focused Improvement, where small groups of employees work together proactively to achieve a regular, incremental improvement in safety and fatigue management, as well as Training to establish responsible behavioral patterns in the management of fatigue of both employees and management. The article also presents a theoretical application of the Overall Labor Effectiveness (OLE) indicator, which is analogous to the Overall Equipment Effectiveness (OEE) indicator for the purposes of fatigue management.

Keywords: Ergonomic design · TPM in fatigue management · Systems engineering · Design for deficits

1 Introduction

Fatigue management is the next step in improving workplace safety. This process progresses along with developing operational excellence in other key areas of an enterprise, such as logistics, production and maintenance. Each has an effect on the enterprise achieving corporate success, and shortcomings in any of these areas can bring about a dangerous dysfunction of the whole system. With the implementation of excellence systems such as Total Productive Maintenance (TPM), enterprises achieve not only a common course of action, but also a common methodology. The applicability of TPM methodology and its related tools was observed while developing a fatigue management system for employees of bituminous coal mines. This, along with macroergonomic considerations of fatigue management, gives an opportunity to implement fatigue management into the context of occupational health and safety

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management systems, and based on that create high functioning decision support for stakeholders.

2 Fatigue Management in the Mining Industry

Interest in fatigue management is particularly evident in areas of human activity where the consequences of even the smallest errors due to fatigue can have tragic consequences. One such area is certainly bituminous coal mining, which both in Poland and around the world is subject to special supervision because of the threat to life involved in underground workings [1–4]. This situation arises due to the specific working conditions in this sector and is associated with the occurrence of virtually all natural hazards, the avoidance of which requires employees to have a significant level of psychomotor performance.

Management is a natural consequence of work performed under certain conditions and time. Increasing exhaustion resulting from undertaken effort (physical or mental–includes readiness for effort) [5] along with human capabilities, establish the curve of the potential to carry out tasks in a work system. The ability to work is multidimensional and its variability is due to both fatigue resulting from exertion and the natural variability in human abilities due to biological rhythms (Fig. 1).

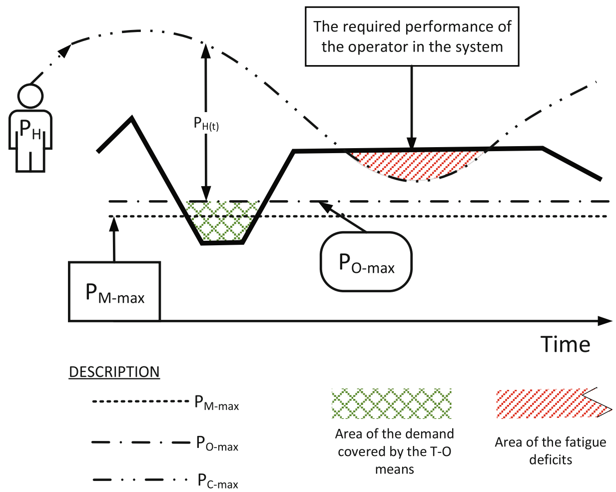

Fig. 1. Fatigue–concept of operator performance (source: own elaboration)

The operator's potential (performance level) supplements the technological and organizational solutions existing in the work environment ($P_{M\text{-max}}$ – maximum machine potential, $P_{O\text{-max}}$ – maximum organizational potential), thereby defining the human potential in that moment $P_{H(t)}$, which equates to the demand. The difference between the points on the curve of the required performance of the system and the curve of human potential, determines the level of excessive fatigue, which in a given industry is classified as satisfactory or unsatisfactory. In the event that technological and organizational measures exceed the requirements of the T-O system, the work system is temporarily self-sufficient and unattended. The operator remains on standby until the need arises (but monitoring itself is an operator's participation in the work system). This approach shows that fatigue management involves the appropriate administration of the course of human potential $P_{H,}$ and the supporting technological and organizational measures $P_{M\text{-max}}$, $P_{O\text{-max},}$ in relation to the requirements generated by the work system and its immediate surroundings (Fig. 2).

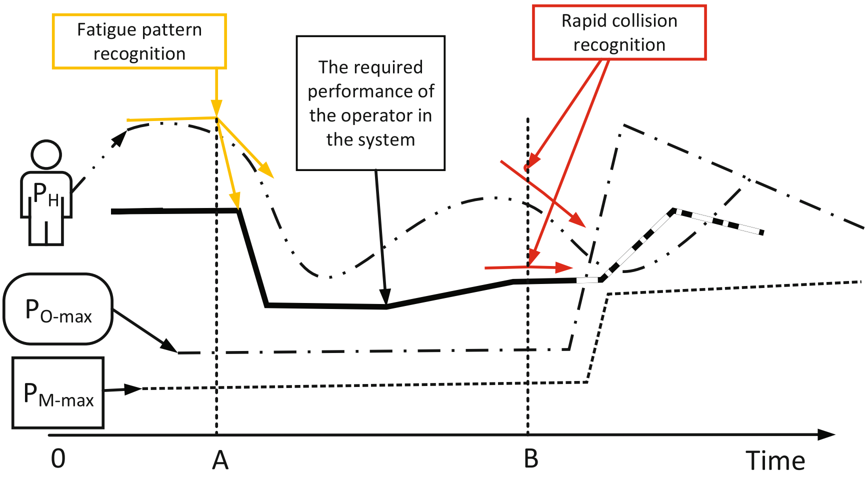

Fig. 2. Fatigue–prevention of operator fatigue (source: own elaboration)

In practice, there is a number of factors associated with the external environment that are crucial to take into account when applying systems and process fatigue management [6]. Basic problems contained in fatigue management include:

- recognition of the symptoms of fatigue before it reaches a level high enough that it threatens the safety of the work system–a number of publications exist on the methods for efficient and non-invasive detection of fatigue [7–9] or systems to recognize performance exhibiting fatigue [10]–a comparison of systems can be found [11], however, subjective measures based on self-reporting are also used [12–14], and are recognized as an efficient tool for the detection of fatigue,
- allocation of tasks to employees in a way that maximizes their potential to perform work, optimizing the risk of fatigue leading to undesirable situations,
- an operator's return to equilibrium from a fatigue state, allowing one to return to performing operations (a way to restore an employee back to work in the system), which is related to the issue of situational awareness and the ability to re-assume responsibility for the tasks performed by the operator (if the system detected a level of fatigue that made it impossible to continue working safely–so-called back in the loop [15]),

- ensuring an appropriately low initial level of fatigue through the management of environmental factors outside of work,
- integration of fatigue management into a company's other activities, in a way that enables the achievement of the aforementioned goals.

In view of the wide range of the above-mentioned mentioned issues, this article presents the ability to systematize activities in a fatigue management system through the use of the TPM approach.

3 TPM and Its Use in Fatigue Management

A modern approach to operation maintenance is the TPM (Total Productive Maintenance) program. This management philosophy includes all employees in the effective management and maintenance of machinery through the elimination of any sources of losses following the client's requirements [16]. The general idea of TPM is to organize repairs within the production team to improve performance of maintenance and production staff and re-design and reconfigure equipment in a manner that makes it more reliable and easier to maintain. This achieves equipment reliability, preventing human terror, and eliminating accidents, which are the main goals of TPM [17, 18]. A desirable side effect of TPM is increasing employee morale and job satisfaction, which also increases worker safety [19]. To achieve this goal, the so-called TPM pillars are used: Focused Improvement, Autonomous Maintenance, Planned Maintenance, Quality Maintenance, Early Equipment Management and Training and Education. All these pillars can be used for the purposes of fatigue management. Among the various techniques used as part of TPM, the techniques that allow better control over the welfare and safety of workers should be highlighted. Some methods of TPM proved particularly useful in fatigue management: Focused Improvement, where small groups of employees work together proactively to achieve a regular, incremental improvement in safety and fatigue management, as well as Training to establish responsible behavioral patterns in the management of fatigue of both employees and management.

Table 1 presents objectives for each of the pillars of TPM with the corresponding actions for fatigue management. Analogously to TPM, where undertaken actions provide continuous and effective machine operation, in fatigue management the same goals are implemented for the employee. In fatigue management, maximizing employee efficiency does not equal maximizing employee effort but its optimization.

The indicators used in TPM methodology may also be implemented in fatigue management. One example would be the Overall Labor Effectiveness (OLE) indicator, which is analogous to the Overall Equipment Effectiveness (OEE) indicator. OLE accumulates three workforce factors [21]:

- Availability: the percentage of time the workforce spends making effective contributions,
- Performance: the amount of product delivered (in mining companies amount of produced coal per shift, team etc.),
- Quality: the percentage of perfect or saleable product produced (quality of produced coal).

Table 1. The application of TPM in fatigue management (own elaboration based on [20]).

TPM pillar	TPM goal and tools	Use of TPM in fatigue management
Autonomous maintenance	Fostering operator ownership–own: cleaning, lubricating, tightening, adjustment, inspection	Anti-fatigue self-control, recognition of states preceding chronic fatigue
Focus improvement	Systematic identification and elimination of losses (5-whys, FMEA, OEE implementation)	Recognition of losses related to human labor, detection of operations that cause unnecessary fatigue, burdening the employee without providing adequate work results
Planned maintenance	Preventive Maintenance (PM) and Predictive Maintenance (PdM)–used tools (PM check sheets, MTBF)	Constantly striving to limit fatigue-inducing factors. Use of MTBF as an indicator of the adequacy of scheduled tasks (repair is understood as the time that will be needed to be able to return to performing work)
Quality maintenance	Zero defects approach M-optimization (machine/man/material/money)	Optimization of work factors and its surroundings in order to reach the absence of overload in any undertaken action
Education & training	Multi-skilling of employees Aligning employees to organizational goals. Periodic skill evaluation and updating	Training and awareness of employees in relation to activities of fatigue management. Staff multitasking to ensure appropriate conditions for rotation and uniform division of load among employees
Safety & environment	Ensure safe working environment	Measures to improve the safety culture, even in the case of high-risk work (mining)
TPM in administration	Improve synergy between various business functions	Enhancement of the tribes and silos value-added approach, improvement in department synergy

The use of OLE indicator in fatigue management involves compiling its value with workplace conditions and the studied work factors. Achieving system synergy (using the remaining TPM tools) allows one to search for losses or unproductive activities. Thus, actions within the work system will be verified according to their impact on the productivity of the workforce.

An important advantage of TPM in fatigue management may be actions that mitigate losses. Examples of the application of particular categories of losses are presented in Table 2.

Losses may seemingly appear to provide relief in a work system by providing unscheduled breaks, however, because they appear randomly and are unpredictable

Table 2. Scope of the application of TPM in fatigue management (own elaboration based on [20]).

Type of loss	Nature of losses, which should be detected and eliminated as part of fatigue management
Breakdown/failure	Working with inefficient/broken equipment
Set-up and adjustment	Breaks due to changeovers improperly utilized
Reduced speed	Working slower than the projected speed of equipment - hardware
Idling and minor stoppage	Stopping flow in the work system which requires corrective action on the part of the operator
Defect and rework	Fatigue resulting from the need to fix defects at work and re-perform/re-work tasks
Start-up	Working during start-up, a long period of adjusting pace after resuming work
Tool changeover	Loss of time and labor on performing tool changes due to damage or wear outside the scheduled period of service
Distribution/logistic	Lack of automation of highly repetitive tasks leading to inefficient human labor
Line organization	Unsynchronized production line causing downtime on the job
Measurement and adjustment	Multiple repetitions of measurement and control tasks
Management	Losses arising from waiting for a decision–instruction, course of action–losses resulting from inadequate division of competences
Motion-related	Lack of motion economy, unnecessary tasks and transitions

they result in increased time pressure during operation (making up losses), and will consequently decrease employee performance.

4 TPM in a Fatigue Management Integration System

Activities in fatigue management (detection of early symptoms, the allocation of tasks in order to reduce the effects of fatigue, etc.) require the application of process changes in the employee management system, which can be included in the following list of requirements [22]:

1. Detailing the scope, objectives and tasks of individual processes–which will help direct focus on how to conduct employees to limit their fatigue by making decisions based on the results of monitoring of selected characteristics of the physical and mental state of employees when performing specified actions.
2. Conducting an in-depth analysis of labor standards and the preparation of changes that reduce the risk of fatigue of workers employed in specific work positions.
3. Introducing cyclical extensive analyses of accidents resulting from fatigue and decision-making on the basis of these findings - to supplement existing procedures or developing new ones.

4. Developing a fatigue factor monitoring system, simultaneously aimed at distinguishing fatigue factors and work positions particularly exposed to the risk of excessive influence of a particular factor.
5. Developing a final list of positions and tasks particularly causing an increase in fatigue, which will form the research sample during the implementation of an employee fatigue management system.
6. Implementing a monitoring system by: selecting the scope of the application of the system, guidelines for its use, those responsible for its use, conducting training for users, support during its first application.
7. Detecting relations resulting from new solutions and introducing them to a schema of IT and physical links between components of the system.
8. Developing a set of measures and norms for an assessment of fatigue at analyzed workstations and periodically comparing the achieved results.
9. Developing measures or indicators testifying to the effectiveness of the worker fatigue management system.
10. Supplementing the description of operations (procedures, instructions) with new or modified activities related to limiting fatigue, but also to carrying out an extended analysis of accidents, training and tutorials, operation of the fatigue factors monitoring system, systematic analysis of data on fatigue factors and decision-making with regard to the prevention of the consequences of fatigue in individual employees as well as an analysis of the system's performance indicators.
11. Confronting the introduced procedural changes with employee representatives, and hence ensuring their acceptance and success in the implementation of changes.
12. Determining which actions are indispensable for employee fatigue management, assigning them clearly defined responsibilities, incorporating them into duties as well as informing the employees.
13. Conducting training and tutorials among staff in order to create favorable attitudes and behavior towards the fatigue management system.
14. Conducting a series of training sessions on improving the quality of sleep and reducing stressful factors and raising individual abilities to limit fatigue resulting from the performed work.

The above-mentioned activities of various strategic level (micro-, meso- and macroergonomic) [23] may be sorted according to a scheme of implementation supported by the TPM method. Despite the fact that ergonomics in fatigue management at the level of work positions will be a very important factor in limiting fatigue, e.g. by adapting the work space [24] or the mental strain of operators [25, 26] there are sought ways to integrate these activities to achieve a higher purpose which is the safety and welfare of workers [27, 28]. A plan for the systemic implementation of fatigue management with the use of TPM is presented in Fig. 3.

Activities related to individual management functions undertaken independently will not have a significant impact on improving fatigue states in workers. The TPM approach may be applied to systematize management activities.

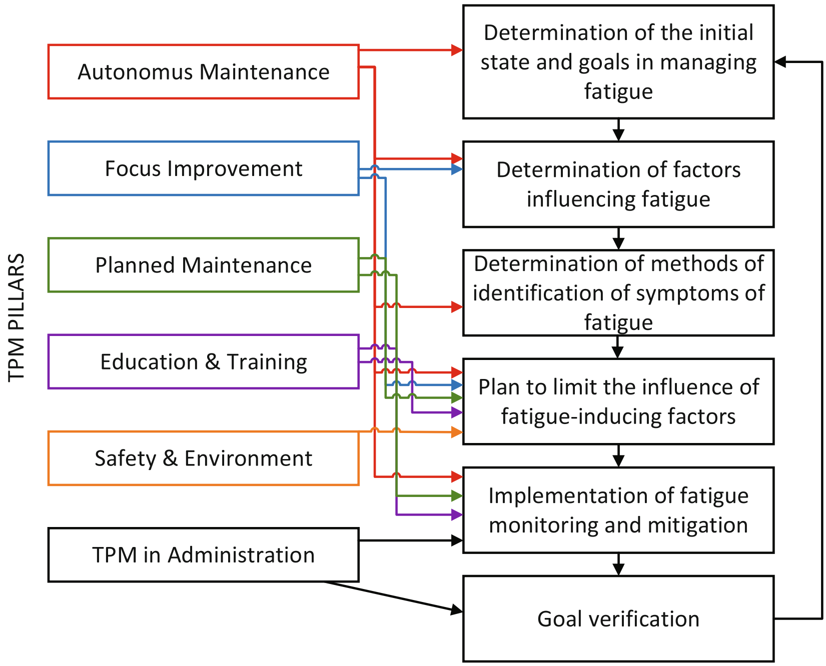

Fig. 3. Fatigue management implementation plan (source: own elaboration based on [29])

5 Conclusions

Fatigue management is a relatively new approach in the fields of management science and production organization. It seems that the next step on the road to excellence of production systems will be resource management in the context of achieving employee welfare. Fatigue management may also be a key factor in the issue of adapting work systems to an aging population. Work performed by the elderly will involve the need to ensure the safety of staff and work systems along with the immediate surroundings. This topic has been given a lot of thought in a number of publications in relation to micro- [30, 31] and macroergonomics [32]. Future work systems will require a much greater level of responsibility, hence the greater need for integration of various systems of business excellence and integration of proven systems such as TPM.

References

1. Homer, A.W.: Coal mine safety regulation in China and the USA. J. Contemp. Asia **39**, 424–439 (2009)
2. Bagherpour, R., Yarahmadi, R., Khademian, A.: Safety risk assessment of Iran's underground coal mines based on preventive and preparative measures. Hum. Ecol. Risk Assess. An Int. J. **21**, 2223–2238 (2015)

3. Piekarski, C., Seyl, G., Bardeleben J.: State of miners' health in Germany, applied occupational and environmental hygiene. In: The Second International Conference on the Health of Miners, vol. 12, pp. 815–819 (1997)
4. Konopko, W. (ed.): Work safety in bituminous coal mines (in Polish: Bezpieczeństwo pracy w kopalniach węgla kamiennego). Górnictwo i środowisko, vol. 1. Główny Instytut Górnictwa, Katowice (2013)
5. Soames-Job, R.F., Dalziel, J.: Defining fatigue as an condition of the organism and distinguishing it from habituation, adaptation and boredom. In: Hancock, P.A., Desmond, P. A. (eds.) Stress, Workload, and Fatigue, p. 471. Erlbaum, Mahwah (2001)
6. Mrugalska, B., Nazir, S., Tytyk, E., Øvergård, K.I.: Process safety control for occupational accident prevention. In: Arezes, P.M., et al. (eds.), Occupational Safety and Hygiene III, pp. 365–369. CRC Press, Taylor & Francis Group, London (2015)
7. Heinze, C., Trutschel, U., Schnupp, T., Sommer, D., Schenka, A., Krajewski, J., Golz, M.: Operator fatigue estimation using heart rate measures. In: World Congress on Medical Physics and Biomedical Engineering, pp. 930–933. Springer, Heidelberg (2009)
8. Krajewski, J., Trutschel, U., Golz, M., Sommer, D., Edwards, D.: Estimating fatigue from predetermined speech samples transmitted by operator communication systems. In: Proceedings International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design, vol. 5, pp. 468–474. University of Iowa Public Policy Center, Iowa City (2009)
9. Trejo, L.J., Knuth, K., Prado, R., Rosipal, R., Kubitz, K., Kochavi, R., Matthews, B., Zhang, Y.: EEG-based estimation of mental fatigue: convergent evidence for a three-state model. In: Schmorrow, D.D., Reeves, L.M. (eds.) Augmented Cognition, HCII 2007. LNAI, vol. 4565, pp. 201–211. Springer, Heidelberg (2007)
10. Sadłowska-Wrzesińska, J., Gabryelewicz, I., Krupa, P.: The use of IT tools for the analysis and evaluation of psychomotor efficiency of employees. In: Oancea, G., Drăgoi,. M.V. (eds.) The 4th International Conference on Computing and Solutions in Manufacturing Engineering, CoSME 2016. MATEC Web of Conferences, vol. 94(06017) (2017)
11. Butlewski, M., Hankiewicz, K.: Psychomotor performance monitoring system in the context of fatigue and accident prevention. Procedia Manuf. **3**, 4860–4867 (2015)
12. Borg, G.A.: Psychophysical bases of perceived exertion. Med. Sci. Sports Exerc. **14**(5), 377–381 (1982)
13. Kaida, K., Takahashi, M., Åkerstedt, T., Nakata, A., Otsuka, Y., Haratani, T., Fukasawa, K.: Validation of the Karolinska sleepiness scale against performance and EEG variables. Clin. Neurophysiol. **117**(7), 1574–1581 (2006)
14. Belz, S.M., Robinson, G.S., Casali, J.G.: Temporal separation and self-rating of alertness as indicators of driver fatigue in commercial motor vehicle operators. Hum. Factors: J. Hum. Factors Ergon. Soc. **46**(1), 154–169 (2004)
15. Inagaki, T.: Smart collaboration between humans and machines based on mutual understanding. Ann. Rev. Control **32**(2), 253–261 (2008)
16. Misztal, A., Butlewski, M., Belu, N., Ionescu, L.M.: Creating involvement of production workers by reliable technical maintenance. In: International Conference on Production Research-Regional Conference Africa, Europe and the Middle East and 3rd International Conference on Quality and Innovation in Engineering and Management, ICPR-AEM 2014, pp. 322–327. Technical University, Cluj-Napoka (2014)
17. Jasiulewicz-Kaczmarek, M., Drożyner, P.: Preventive and pro-active ergonomics influence on maintenance excellence level. In: Robertson, M.M. (ed.) Ergonomics and Health Aspects, HCII 2011. LNCS, vol. 6779, pp. 49–58. Springer, Berlin Heidelberg (2011)
18. Grzybowska, K., Gajdzik, B.: Optimisation of equipment setup processes in enterprises. Metalurgija **51**(4), 563–566 (2012)

19. Mrugalska, B., Arezes, P.M.: An investigation of safety design practices of metal machines. Work: A J. of Prev. Assess. Rehabil. **51**(4), 747–755 (2015)
20. Ahuja, I.P.S., Khamba, J.S.: Total productive maintenance: literature review and directions. Int. J. Qual. Reliab. Manage. **25**(7), 709–756 (2008)
21. Kronos: Overall Labor Effectiveness (OLE): Achieving a Highly Effective Workforce. http://www.workforceinstitute.org/wp-content/uploads/2008/01/ole-achievinghighly-effective-workforce.pdf, Accessed 20 Sep 2016
22. Butlewski, M., Misztal, A.: Direction of process management in a worker fatigue management system. The Małopolska School of Economics in Tarnów Research Papers Collection (in Polish: Kierunki zmian procesowych w systemie zarządzania zmęczeniem pracowników). Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie, **3**(31), 71–82 (2016)
23. Butlewski M., Tytyk E.: The assessment criteria of the ergonomic quality of anthropotechnical mega-systems. In: Vink, P. (ed.) Advances in Social and Organizational Factors, pp. 298–306. CRC Press, Taylor and Francis Group, Boca Raton (2012)
24. Vujica-Herzog, N., Vujica Beharić, R., Beharić, A., Buchmeister, B.: Ergonomic analysis of ophthalmic nurse workplace using 3D simulation. Int. J. Simul. Model. **13**(4), 409–418 (2014)
25. Butlewski, M., Slawinska, M.: Ergonomic method for the implementation of occupational safety systems. In: Arezes, P., et al. (eds.) Occupational Safety and Hygiene II, pp. 621–626. CRC Press, Taylor & Francis Group, London (2014)
26. Górny, A.: Minimum safety requirements for the use of work equipment (for example of control devices). In: Arezes, P., et al. (eds.) Occupational Safety and Hygiene, pp. 164–165. Portuguese Society of Occupational Safety and Hygiene (SPOSHO), Guimarães (2013)
27. Górny, A.: Ergonomics in the formation of work condition quality. Work J. Prev. Assess. Rehabil. **1**(supp. 1), 1708–1711 (2012)
28. Górny, A.: The use of working environment factors as criteria in assessing the capacity to carry out processes. In: Oancea, G., Drăgoi, M.V. (eds.) The 4th International Conference on Computing and Solutions in Manufacturing Engineering, CoSME 2016. MATEC Web of Conferences, vol. 94(04011) (2017)
29. Total Productive Maintenance. http://isoconsultantpune.com/total-productive-maintenance/, Accessed 20 Jan 2017
30. Lis, K.: The labour market and material environment design. In: Vink, P. (ed.) Advances in Social and Organizational Factors, pp. 603–612. CRC Press, Taylor & Francis Group, Boca Raton (2012)
31. Butlewski, M.: Practical approaches in the design of everyday objects for the elderly. Appl. Mech. Mater. **657**, 1061–1065 (2014)
32. Butlewski, M., Tytyk, E., Wróbel, K.: Macroergonomic model of quality of life of elderly employees for design purposes. In: Vink, P. (ed.) Advances in Social and Organizational Factors. AHFE Conference, pp. 252–260 (2014)

Methodology of Maturity Level Rating for Macro Ergonomic System in Area of Sustainable Development

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Abstract. Paper concerns methodology of macro ergonomic system maturity level rating. The technique is design for wide range of branches and may be useful for companies, where size and reputation have no matter. Sustainability as a meaningful part of the strategy in modern business and plays important role in building competitive advantage. Elaborated methodology among other methods uses Delphi method as a technique for receiving information from bigger and more competent group of stakeholders or specialists. Procedure gaining excellence path as a final effect of elaboration is based on pointing out the area of macro-ergonomic system and its most important indicators, but also simple equations. This makes methodology easy in use to rank maturity level in the range of sustainability not only in holistic approach. It is possible to perform an action for simple processes and specific actions and modules of the company.

Keywords: Excellence · Maturity model · Sustainability

1 Introduction

Competitive advantage acquisition by present day companies should be provided as a quick reaction related dynamic vicissitudes. The origin of these changes can be sustainable development assumptions as a link of organizational improvement. Corporate sustainability constituted business answer for this norms but also is understood as approach concentrated on economical, ecological and social features.

Several methodologies, methods and techniques helpful in gaining improvement information were elaborated and linked in scientific literature. This group includes tools, such as maturity models, which the most important part of usage are data objective implementation and appropriate procedure their transformation. Measurements require also key factors elaboration, that will impact on kind and quantity of data.

Sustainable development definition was written for the first time by the Brundtland Commission and was accepted as a definition of the standard [1]. The role of business is defined as a necessity reduction negative results of business activity [2].

Sustainable development assumptions identification plays a key role in the business activity. Proper comprehension is also important to provide responsible activity and create added value for the internal and external community [3]. The author accepted a

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definition of sustainable development in which conception has a high priority of meeting basic needs of current and next generations.

Business response for sustainable development assumptions is an idea called corporate sustainability. This approach takes into account aspects such as an economy, ecology and social factor maintaining balance in their exploitation. In addition, conception suggests the direction of business unit improvement, compatible with sustainability at the same time. Summarizing business sustainability state oneself on triple bottom line performance with long-lasting core ideals and behaviours based on universal values [4].

Corporate sustainability is a conception that can be measured using several different tools and methods. Studies over this occurrence are often provided with maturity models.

Maturity models because of their structure, measurable results and their improvement find usage in several different branches. Pioneering maturity model was elaborated in the case to valuate quality of management in a business environment [5]. It allowed compiling a wide group of maturity models concerning problems such as organization capabilities including safety, energy, research and development, project management and teamwork [6].

Each maturity model is consisting of defined number of levels and each of them can be defined as an evolutionary plateau of process improvement. Achievement new higher stage means that company or its unit has to face with new expectations in process of self-improvement [7].

Model structure tool application requires also to prepare a set of indicators and adoption already elaborated which in further stages will determine the source of information and present process or set of processes where development is most needed. These factors may be treated as tasks, processes, abilities or features, that should be fulfilled for the successful end development [6].

The purpose of the article is to elaborate a procedure for ranking macro-ergonomic system maturity level in the area of sustainable development.

2 Methodology of Maturity Level Rating in Area of Sustainable Development

Presented methodology in this paper is a shortened elaboration research and barrier identification under doctoral dissertation directed in maturity rating of a macro-ergonomic system. The procedure concerned design for companies of different sizes and functioned in different branches.

The methodology may be used for gaining competitive advantage which concerns sustainability development in modern business. Figure 1 presents an algorithm of procedure coherent with an elaborated method of company maturity level rating.

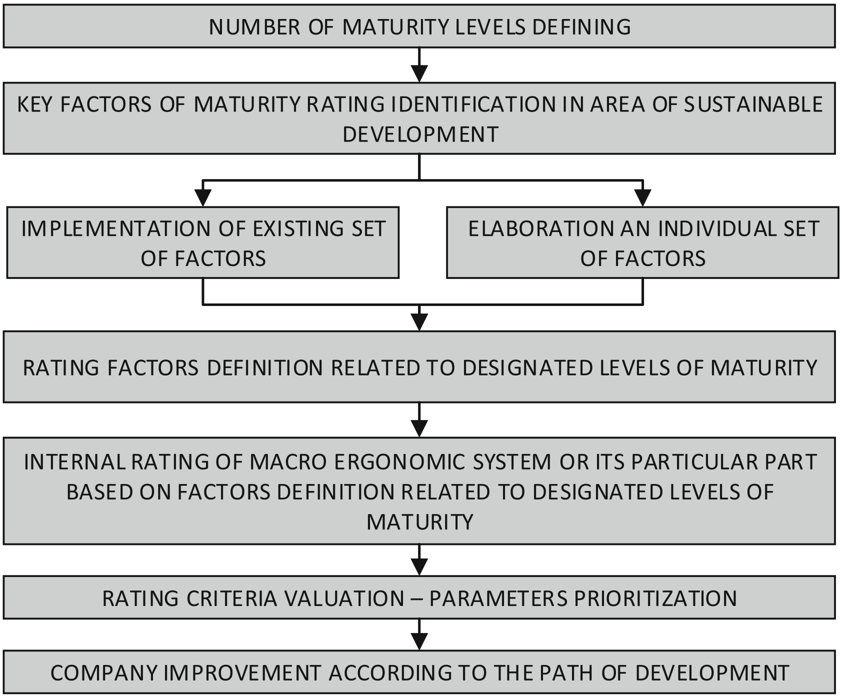

Fig. 1. Methodology algorithm. Own study.

2.1 Maturity Levels Definition

Achievements of literature in the range of maturity models are very impressive. A feature of each model is a possibility of identification current level of development is the particular aspect, assuming that each level requires fulfilling unique barriers and foundations.

It is also important, that the company will reach higher levels in correct order. Otherwise, activities provided to business development will befall started with no positive result. Table 1 included a general characteristic of maturity levels in reference to maturity models of different structures.

The author decided to distinguish four levels of maturity in elaborated model such as beginning, elementary, satisfying and sophisticated. Most of the compiled models presented in literature consist of four to five levels, what makes an assumption about a number of levels compatible. It is possible that model implication will be correct in case of the lower number of levels to achieve full maturity. It will make a macro-ergonomic system easier to identify current situation and plan further improvements, especially those, which haven't plan their business activity in compliance with sustainable development. It is important to ascribe weight for each level, where each weight would be adequate and proportional in relation to maturity level. For article requirements the following allocation has been used; beginning – 2, elementary – 3, satisfying – 4, sophisticated – 5.

Table 1. Maturity levels definition comparison [4, 5, 8–11].

<table>
<tr><th rowspan="2">Level</th><th colspan="2">Description</th></tr>
<tr><th>5 – level maturity model</th><th>4 – level maturity model</th></tr>
<tr><td>Functional muddle</td><td colspan="2">Processes identification is informal, their implementation isn't regular and is more chaotic</td></tr>
<tr><td>Searching for recurrence</td><td colspan="2">Processes identification is formal, results depend on the unified procedure. Simple techniques of results measurement are implement</td></tr>
<tr><td>Full recurrence</td><td>All processes identification is formal, beginning with process management, whereby results and predicted expectations recur</td><td rowspan="2">All processes are defined, visualized and measured, results and expectations recur. Motivation system is starting to taking place in company</td></tr>
<tr><td>Process management</td><td>All processes identification is formal, they are defined and visualized, regular measurement of results, beginning with motivation system</td></tr>
<tr><td>Searching for excellence</td><td colspan="2">The company is concentrated on process improvement. Full involvement of employees is visible, as also organizational culture take place. Core values improve processes</td></tr>
</table>

2.2 Key Factors Identification

Key factors are important component of every maturity model. According to each model, these criteria may be designated directly or used to create a set of requirements description of achievement particular maturity level. The elaborated model takes into account two ways of receiving a set of key factors in the area of sustainable development.

2.3 Key Factors Set Implementation

Taking benefits from a ready set of factors is useful mainly for the macro-ergonomic system, which hasn't earlier planned their activities grounded on sustainability and don't understand fully idea of the conception. This option gives usage from elaborated model and its conclusions without skipping any important features of sustainability. This variant is also recommended for companies that don't know which process or group of processes should be improved in the first place.

An attempt of universal key factors identification related to sustainable development was given by Baumgartner and Ebner. Their research also concern division to the main aspects of sustainability which are included in Table 2.

Table 2. Key criteria of sustainable development [6].

Economic aspect	Innovation & technology			
	Collaboration			
	Knowledge management			
	Processes			
	Purchase			
	Sustainability reporting			
Ecological aspect	Resources (materials, energy) including recycling			
	Emissions into the air, water or ground			
	Waste and hazardous waste			
	Biodiversity			
	Environmental issues of the product			
Social aspect	Internal	Corporate governance	External	Ethical behaviour and human rights
		Motivation and incentives		No controversial activities
		Health and safety		No corruption and cartel
		Human capital development		Corporate citizenship

2.4 Individual Set of Key Factors Elaboration

Company improvement based on elaboration set of indicators should be used by these systems, which are high awareness in sustainability or which made their firsts steps in sustainable development. Factors selection requires big amount of collected information. That will make a restriction and will streamline on particular process or problem. Independently from the scale of the problem, it will be necessary to reduce results to the most important components having the most strategic influence on researched object. There is a wide range of tools that can be used to reduce a number of factors, however the author considered the Delphi method as the most effective. A big advantage of this technique is the possibility of gathering different data after it's executing in the internal and external environment. According to the problem, a required information should be gathered from employees or a group of specialists. Obtained data from business partners placed in different levels of the structure will make results more horizontal and holistic. Using specialists knowledge has more meaning in gaining information about management as well as a wider range of problems that require scientific approach skill. Next step is to plan a way to collect and analyse obtained data. Specialist related with sustainable development elaborated a group of questions as well as set of requirements necessary to fulfil and decide if particular indicator can be called strategic and important. The questions example are following:

– Does the indicator provide a long-term view of the community?
– Does the indicator measure a link between society and economy?
– Does the indicator address the carrying capacity of the ecosystem services upon which the community relies, whether local, global, or from distant sources?

For the article requirements a ready set of factors has been used that concerns external social aspect, including ethics and human rights, no controversy in business, no corruption and corporate citizenship.

2.5 Definition of Criteria on Different Level of Maturity

Detailed analysis of each level of maturity is required for proper current status identification in the area of the company, which will be the starting point for improvements. General data about levels of maturity such as level of advanced process management, their unification, measurability and continuous improvement isn't enough. Detailed elaboration will have an influence on objective grading and benefits. Characteristics of sustainable development aspects are presented in Tables 3, 4, 5. Tables are based on research provided by Baumgartner and Ebner and concerns key criteria divided into different maturity levels.

Table 3. Definitions of key indicators in economical aspect [12].

	Beginning	Elementary	Satisfying	Sophisticated
Collaboration	The company is not an active partner in networks	Collaboration with most relevant business partners	Communication with stakeholders regarding sustainability issues	Consequent communication with stakeholders is conducted. The the company has a proactive role in creating networks
Knowledge management	No systematic approach	Some activities are conducted in order to save sustainability	Integrating intangible assets	A systematic and a comprehensive approach towards sustainability is implemented

Table 4. Definitions of key indicators in ecological aspect [12].

	Beginning	Elementary	Satisfying	Sophisticated
Emissions into the air, water or ground	Conformity with laws regarding emissions	Definition of reduction goals for major emissions	Goals for most emissions are defined. Cleaner production technologies are used	Ambitious goals for air emissions are defined. activities due to zero emission are avoided
Waste and hazardous waste	Conformity with laws regarding waste	Definition of reduction goals for major waste flow	Goals for most emissions are defined. Cleaner production technology is used	Ambitious reduction goals for waste flows are defined, waste is avoided due to zero emission activities

Table 5. Definitions of key indicators in the social aspect [12].

	Beginning	Elementary	Satisfying	Sophisticated
Corporate governance	Mandatory frameworks are focused on	Voluntary frameworks are focused on	Further measures to ensure corporate transparency are set	Proactive commitment respective stronger rules are given
Health and safety	Health is respected to the extent of legal obligation	Measures towards health and safety are set, when accidents occur	Health and safety is systematically planned and deployed in most areas of the company	Various education programs and measures are offered. Most employees are trained regarding sustainability issues

2.6 Internal Rating of a Macro-Ergonomic System or Its Restricted Area

At this stage of methodology, company performs self-evaluation based on factor characteristics on separated maturity levels. The objective approach is very important, otherwise, the improvement path will suggest wrong queue of development.

Self-evaluation presented in the article concerns beginning level for ethics, human rights and no corruption and sophisticated level for controversial activities. Corporate citizenship aspect was evaluated in reference to a satisfying level.

2.7 Criteria Rating Valuation

Hierarchy of criteria maturity rating of a macro-ergonomic system is a key issue related to final conclusions. Weight values will play an important role in designing the development path.

Valuation can take place using the Delphi method and as in the case of criteria selection this method may be concentrated on internal employees experience or external knowledge of specialists. Group of experts should have been selected because of their experience and knowledge. Selected group of experts ascribes values for each criterion in defined and analytical way. Values should be set in defined range and shouldn't repeat. Result of this action will be gathered information based on reliable sources and long-term analysis.

In this paper, a major indicators were attributed to the following weights; Ethics and human rights – 0,8, controversial activities – 0,6, no corruption – 0,9 and corporate citizenship – 0,4.

2.8 Company Improvement Compatible with the Path of Development

At this stage of methodology, the result of previous actions is a diagram including:

- Number of maturity levels and ascribed weights,
- Set of key success factors and ascribed weights,
- Analysed and rated current status of a macro-ergonomic system.

INDICATORS		MATURITY LEVELS WITH WEIGHTS			
		2	3	4	5
	WEIGHTS	BEGINNING	ELEMENTARY	SATISFYING	SOPHISTICATED
ETHICS AND HUMAN RIGHTS	0,8	1,6	2,4	3,2	4
NO CONTROVERSIAL ACTIVITIES	0,6	1,2	1,8	2,4	3
NO CORRUPTION	0,9	1,8	2,7	3,6	4,5
CITIZENSHIP CORPORATE	0,4	0,8	1,2	1,6	2

Fig. 2. First stage of methodology - current position analyse. Own elaboration.

An exemplary diagram is presented in Fig. 2, which design is based all available information mentioned earlier.

Figure 2 presents maturity levels in the area of defined sustainable development criteria. Key success indicator has been selected in self-evaluation process. Levels have been designated with the usage of red lines and values inside concerns meaning of particular aspect for the company as a product of criteria weight-related for each level of maturity.

Next step consists of designing development path, which will point the best directions of improvement in proper order. The company will have a clear view which processes or group of them should be modified to let it reach the highest maturity level.

Path designing requires correct analysis of values. This will permit to achieve new higher level with new requirements more hard to accomplish.

The procedure of designating the first aspect of improvement has been attached in Fig. 3.

Indicator controversial activities aren't taken into account because group of experts estimated its level of maturity on the highest level. Considerations concerns only last three of key success factors, which are ethics and human rights (rated at about 2, 4), no corruption (rate 2, 7) and corporate citizenship (rate 1, 6). According to elaborated methodology, first aspect being improved should be no corruption, because of the highest value (2, 7). In addition, the value of this aspect in next level is higher than the others (3, 6), so the second round of betterment also has to refer to it.

INDICATORS		MATURITY LEVELS WITH WEIGHTS			
		2	3	4	5
	WEIGHTS	BEGINNING	ELEMENTARY	SATISFYING	SOPHISTICATED
ETHICS AND HUMAN RIGHTS	0,8	1,6	2,4	3,2	4
NO CONTROVERSIAL ACTIVITIES	0,6	1,2	1,8	2,4	3
NO CORRUPTION	0,9	1,8	2,7	3,6	4,5
CITIZENSHIP CORPORATE	0,4	0,8	1,2	1,6	2

Fig. 3. Second stage of methodology. Own elaboration.

Improvement path for all indicators is presented in Fig. 4.

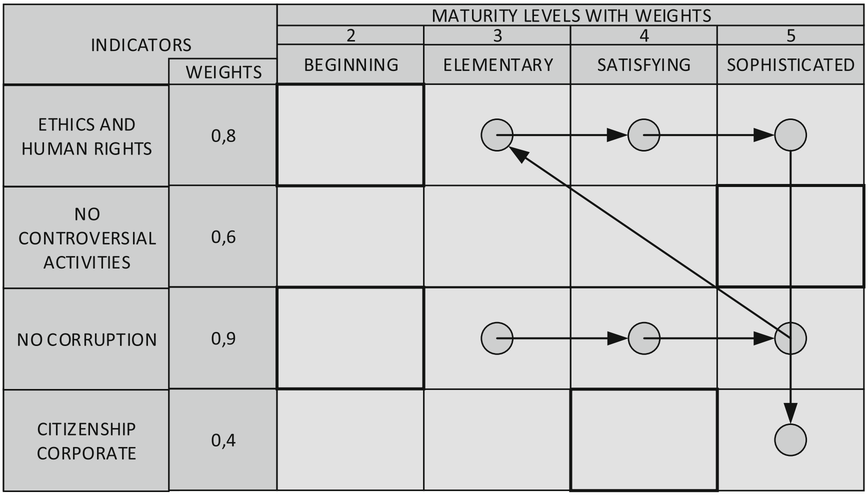

Fig. 4. Final stage of methodology - development path. Own elaboration.

3 Conclusions

An elaborated methodology has been designed for companies which are starting business activities related to sustainability, as well as macro-ergonomic systems, which has already based their strategy on sustainable development. This tool may be used regardless to branch or size of the company. An advantage is a wide universalism, thanks to which company can select indicators and analytical criteria and build their strategy not only in regard to sustainable assumptions but also other restrictions. An important part of the methodology are benefits resulting from objective approach during research, a technique for converting and interpreting data and correct procedure.

Research has been provided in the range of doctoral dissertation, which will be related to develop a previous procedure of analysis of data and performing a simulation of its usage at an example.

References

1. Our Common Future: World Commission on Environment and Development. Oxford Univ. Press, Oxford (1987)
2. Sidorczuk-Pietraszko, E.: The concept of sustainable development at organizational level. In: Towards the Theory of Sustainable Development, Polish Academy of Science. Studies on Sustainable Development (2007)
3. Robinson, H.S.: STEPS: a knowledge management maturity roadmap for corporate sustainability. Bus. Process Manage. J. **12**(6), 793–808 (2006). Bradford
4. Jasiulewicz-Kaczmarek, M., Drożyner, P.: Preventive and pro-active ergonomics influence on maintenance excellence level. In: Robertson, M.M. (ed.) Ergonomics and Health Aspects, HCII 2011. LNCS, vol. 6779 pp. 49–58. Springer, Heidelberg (2011)
5. Mazur, A., Stachowiak, A.: The framework of methodology for identification of organizational maturity with assessment of excellence level of logistics systems. In: Abrudan, I. (ed.) The Management Between Profit and Social Responsibility. Proceedings of the 4th Review of Management and Economic Engineering International Management Conference, 18–20 September 2014, pp. 415–423. Todesco Publishing House, Cluj-Napoca (2014)
6. Szczuka, M.: Key success factors of company maturity in area of sustainability development – state of art. In: ESME Conference (2016)
7. Visser, W.: Corporate Sustainability and the Individual A Literature Review, Cambridge Programme for Sustainability Leadership Paper Series, No. 1, 1–15 (2007). http://www.waynevisser.com/wp-ontent/uploads/2007/05/paper_sustainability_individual_lit_wvisser.pdf. Accessed 28 Jan 2015
8. Butlewski, M., Misztal, A., Jasiulewicz-Kaczmarek, M., Janik, S.: Ergonomic and work safety evaluation criteria od process excellence in the foundry industry. Metalurgija **53**(4), 701–704 (2014)
9. Crosby, P.B.: Quality is Free: The Art of Making Quality Certain. New York (1979)
10. Röglinger, M., Pöppelbuß, J., Becker, J.: Maturity models in business process management. Bus. Process Manage. J. **18**, 328–346 (2012)
11. Skrzypek, E., Hofman, M.: Zarządzanie procesami w przedsiębiorstwie. Wyd. Wolters Kluwer, Warszawa (2010)
12. Baumgartner, R.J., Ebner, D.: Corporate sustainability strategies: sustainability profiles and maturity levels. Sustain. Dev. **18**(2), 76–89 (2010)

Spread Page Approach to Document Management

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Abstract. The paper describes the use of new possibilities of the Spread Page notation for knowledge representation, such as Three-dimensional Representation, Time-varying Representation, Layered Representation, Scaled Detail Representation, Aspect-oriented Representation to describe metadata and the dynamics of displacement of documents in the restricted access administrative office. The knowledge representation methods have been developed allowing you to describe in a single model both static and dynamic properties of objects.

Keywords: Spread page · Systems engineering · Knowledge representation · Data model · Document management · Aurea BPM

1 Introduction

For millennia, science has been crafted, practiced and passes over with writings and drawings – on clay tablets, papyrus scrolls or paper pages. We have grown accustomed, and quite frankly, addicted to such flat, two-dimensional, mostly monochromatic representation of knowledge – based on written languages, occasionally enriched with (2-D) figures and drawings. Arguably, the limitations forced by the medium – a paper page – guided the birth and evolution of all notations currently used in any scientific discipline: from biology, medicine or chemistry to math and computer science. Today's signum temporis is the "rectangular box with a name in it" which became the most predominant element of graphical representations used to model just about anything.

New technologies and media have brought significant improvements. Today, one (electronic) tablet can hold and present contents of thousands weighty books (or a truckload of clay tablets), hyperlinked text (in HTML, PDF) allows the reader to pass instantaneously from one text fragment to another without having to (look for books on the shelf and) flip pages. Multimedia became an indigenous component of presented content. Today's electronic devices are inexpensive, handy and robust; their screens are increasingly eye-friendly, quickly and precisely react to touch, soon enough they will provide tactile feedback and true 3D display capabilities. All that clearly enables us to use new, intuitive, interactive, dynamic ways of presenting content [1].

Workflow or Business Process Management means definition, execution and automation of business processes where tasks, information and documents are passed from one participant to another to perform certain work, according to a process definition [2–4].

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Organizations use workflows to coordinate tasks between people and synchronize data between systems, with the goal of improving organizational efficiency [5, 6].

The paper describes the use of new possibilities of the Spread Page notation for knowledge representation, such as Three-dimensional Representation, Time-varying Representation, Layered Representation, Scaled Detail Representation, Aspect-oriented Representation to describe metadata and the dynamics of displacement of documents in administrative office. The knowledge representation methods have been developed allowing you to describe in a single model both static and dynamic properties of objects.

2 Spread Page Model Representations

Scientific modelling is a scientific activity, the aim of which is to make a particular part or feature of the world easier to understand, define, quantify, visualize, or simulate by referencing it to existing and usually commonly accepted knowledge. It requires selecting and identifying relevant aspects of a situation in the real world and then using different types of models for different aims, such as conceptual models to better understand, operational models to operationalize, mathematical models to quantify, and graphical models to visualize the subject [7, 8].

It is very easy to confuse models and visualizations because they are very closely related. To draw out the distinction between model and visualization we can define a model as an abstract information – a set of design decisions. Visualizations give those design decisions form: they let us depict those design decisions and interact with them in different ways. In other words visualizations are forms of model representations.

Visualization is any technique for creating images, diagrams, or animations to communicate a message. Visualization through visual imagery remains the most effective way to communicate both abstract and concrete ideas.

There are several Spread Page model representations. Each of them can be used to illustrate different aspect of a model being designed.

2.1 Three-Dimensional Representation

Three-dimensional (3D) models represent a physical object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling), or scanned. Their surfaces may be further defined with texture mapping.

Today, 3D models are used in a wide variety of fields. The medical industry uses detailed models of organs; these may be created with multiple 2-D image slices from an MRI or CT scan. The movie industry uses them as characters and objects for animated and real-life motion pictures. The video game industry uses them as assets for computer and video games. The science sector uses them as highly detailed models of chemical compounds [9]. The architecture industry uses them to demonstrate proposed buildings and landscapes in lieu of traditional, physical architectural models. The engineering community uses them as designs of new devices, vehicles and structures as well as a host of other uses. In recent decades the earth science community has started to construct 3D geological models as a standard practice. 3D models can also be the basis for physical devices that are built with 3D printers or CNC machines.

2.2 Time-Varying Representation

In many scientific disciplines, there are models with elements or relations between them that vary in time. Dynamic networks are one of many examples. They are very often described as time-varying graphs which consist not only with node and edge sets but also have an additional time instants set that stores changes in the graph with time [10].

Time-varying models could be viewed as a film-strap object that allows skipping from the given point in time to the next one or the previous one. It could also play an animated movie for the given period of time.

2.3 Layered Representation

Modern digital maps are in fact collections of layers. At the beginning, digital maps had the same basic functionality as paper maps. They were just pictures representing roads outlined by the terrain encompassing the surrounding area. However, as digital maps have grown with the expansion of GPS technology in the past decade, live traffic updates [11], points of interest and service locations have been added to enhance digital maps to be more "user conscious" [12]. Traditional map views are now only part of digital mapping. In many cases, users can choose between virtual maps, satellite, and hybrid views.

However layered representation is used not only for geographical mam representation. Layers are commonly used in digital image editing and processing. In medical image analysis layers are very powerful tools for collecting data from different sources, presenting them together, separating different parts of image analyzed, and supporting doctors in decision making.

Many scientific notations can be represented as layers. This approach allows us to present individual aspects of constructed model on different layers and analyze them separately or together, depends on layer visibility settings.

2.4 Scaled Detail Representation

I geography, the larger the scale of the map, the better the features that can be detailed. A map that shows the water network of a small area may show the river as a polygon layer and will show the tributaries of that river. A small scale map covering the area would show that same river as a line feature and the tributaries would be removed (a process known as generalization). The smaller the scale of the map, the less the actual detail of a feature is preserved [13].

Computer graphics and animation systems use scaled detail approach to object representation. There is no need to draw every detail of an object that appears at a very long distance from the observer. However, in case when the same object approaches the observer it is necessary to unhide its details to make it look good at the screen.

In scientific models sometimes there is a need for looking at the model "from the distance". That kind of view could be un-detailed. For instance at the general view of data model there is no need to show all attributes of entities. Rectangles representing entities, their names inside, and lines representing relations between them would be enough.

2.5 Aspect-Oriented Representation

Sometimes a model could have a slightly different meaning depends on whom it is addressed to. For instance if we could imagine a model of a legal agreement, different parts of that model are important for different persons involved in approval and signing of it. Instead of delivering to them the whole text of the agreement, they could receive that parts that are important especially for them, and in the form they prefer. This is the main point of aspect-oriented representations.

3 Document Management

Document management is the process of applying policies and rules to how documents are created, persisted, and expired within an organization. Document collaboration is merely the process of checking out, checking in, and versioning a document before it is published.

The main aspects of managing documents through a life cycle include the following [14]:

Metadata. Metadata is typically stored for each document. Metadata may, for example, include the date the document will be stored and the identity of the user storing it. The DMS may also extract metadata from the document automatically or prompt the user to add metadata. Some systems also use optical character recognition on scanned images, or perform text extraction on electronic documents. The resulting extracted text can be used to assist users in locating documents by identifying probable keywords or providing for full text search capability, or can be used on its own. Extracted text can also be stored as a component of metadata, stored with the image, or separately as a source for searching document collections.

Integration. Many document management systems attempt to integrate document management directly into other applications, so that users may retrieve existing documents directly from the document management system repository, make changes, and save the changed document back to the repository as a new version, all without leaving the application. Such integration is commonly available for office suites and e-mail or collaboration/groupware software. Integration often uses open standards such as ODMA, LDAP, WebDAV and SOAP to allow integration with other software and compliance with internal controls.

Capture. Capture primarily involves accepting and processing images of paper documents from scanners or multifunction printers. Optical character recognition (OCR) software is often used, whether integrated into the hardware or as stand-alone software, in order to convert digital images into machine readable text. Optical mark recognition (OMR) software is sometimes used to extract values of check-boxes or bubbles. Capture may also involve accepting electronic documents and other computer-based files.

Validation. Visual validation registration system and important data. E.g. document failures, missing signatures, misspelled names, this can be printed on paper documents or images on paper.

Indexing. Indexing tracks electronic documents. Indexing may be as simple as keeping track of unique document identifiers; but often it takes a more complex form, providing classification through the documents' metadata or even through word indexes extracted from the documents' contents. Indexing exists mainly to support retrieval. One area of critical importance for rapid retrieval is the creation of an index topology.

Storage and Location. Store electronic documents. Storage of the documents often includes management of those same documents; where they are stored, for how long, migration of the documents from one storage media to another (hierarchical storage management) and eventual document destruction. The Location means a physical location where documents will be stored and accessed.

Filing. The placement of the hard copy of the document in a storage, cabinet, box, etc. For electronic systems, documents placed in the physical location are also described by their metadata. The metadata files the document logically by allowing the document to be found based on the metadata values assigned to the document.

Retrieval. Retrieve the electronic documents from the storage. Although the notion of retrieving a particular document is simple, retrieval in the electronic context can be quite complex and powerful. Simple retrieval of individual documents can be supported by allowing the user to specify the unique document identifier, and having the system use the basic index (or a non-indexed query on its data store) to retrieve the document. More flexible retrieval allows the user to specify partial search terms involving the document identifier and/or parts of the expected metadata. This would typically return a list of documents which match the user's search terms. Some systems provide the capability to specify a Boolean expression containing multiple keywords or example phrases expected to exist within the documents' contents. The retrieval for this kind of query may be supported by previously built indexes, or may perform more time-consuming searches through the documents' contents to return a list of the potentially relevant documents. See also Document retrieval.

Distribution. A published document for distribution has to be in a format that can not be easily altered. As a common practice in law regulated industries, an original master copy of the document is usually never used for distribution other than archiving. If a document is to be distributed electronically in a regulatory environment, then the equipment tasking the job has to be quality endorsed AND validated. Similarly quality endorsed electronic distribution carriers have to be used. This approach applies to both of the systems by which the document is to be inter-exchanged, if the integrity of the document is highly in demand.

Security. Document security is vital in many document management applications. Compliance requirements for certain documents can be quite complex depending on the type of documents. For instance, in the United States, the Health Insurance Portability and Accountability Act (HIPAA) requirements dictate that medical documents have certain security requirements. Some document management systems have a rights management module that allows an administrator to give access to documents based on type to only certain people or groups of people. Document marking at the time of printing or PDF-creation is an essential element to preclude alteration or unintended use.

Workflow. Workflow is a complex process and some document management systems have a built-in workflow module. There are different types of workflow. Usage depends on the environment to which the electronic document management system (EDMS) is applied. Manual workflow requires a user to view the document and decide whom to send it to. Rules-based workflow allows an administrator to create a rule that dictates the flow of the document through an organization: for instance, an invoice passes through an approval process and then is routed to the accounts-payable department. Dynamic rules allow for branches to be created in a workflow process. A simple example would be to enter an invoice amount and if the amount is lower than a certain set amount, it follows different routes through the organization. Advanced workflow mechanisms can manipulate content or signal external processes while these rules are in effect.

Collaboration. Collaboration should be inherent in an EDMS. In its basic form, collaborative EDMS should allow documents to be retrieved and worked on by an authorized user. Access should be blocked to other users while work is being performed on the document. Other advanced forms of collaboration act in real time, allowing multiple users to view and modify (or markup) documents at the same time. The resulting document is comprehensive, including all users additions. Collaboration within Document Management Systems stores the various markups by each individual user during the collaboration session, allowing document history to be monitored.

Versioning. Versioning is a process by which documents are checked in or out of the document management system, allowing users to retrieve previous versions and to continue work from a selected point. Versioning is useful for documents that change over time and require updating, but it may be necessary to go back to or reference a previous copy.

Searching. Searching finds documents and folders using template attributes or full text search. Documents can be searched using various attributes and document content.

Federated Search. This refers to the capability to extend search capabilities to draw results from multiple sources, or from multiple DMSes within an enterprise.

Publishing. Publishing a document involves the procedures of proofreading, peer or public reviewing, authorizing, printing and approving etc. Those steps ensure prudence and logical thinking. Any careless handling may result in the inaccuracy of the document and therefore mislead or upset its users and readers. In law regulated industries, some of the procedures have to be completed as evidenced by their corresponding signatures and the date(s) on which the document was signed.

Different kinds of documents can be subject to the document management. That may be electronical documents as well as hard copied paper documents. Documents are described by static parameters such as their content, metadata, structure, purpose, ownership, and dynamic parameters such as their versions, change history, displacement history, traceability. The most important aspect of document management from the Spread Page point of view seems to be document flow.

However, document security aspects are also very important, especially for documents with different levels of confidentiality. The values for the security level depend on four security aspects: confidentiality, integrity, authenticity and traceability [15, 16].

- Confidentiality means protection against unauthorized notice, i.e. no one else except the sender and receiver of a document should be able to read it during the transportation.
- Integrity stands for the protection of documents against unauthorized modification. Data must not be changed during transportation. The modification may be caused mechanically, i.e. due to a technical error, or deliberately by an attacker.
- Authenticity covers the assurance that the sender sent the document, i.e. it has to be assured that it is impossible for an attacker to send a message by adopting the identity of the original sender.
- Traceability means that it can be proofed who sent a document and who received it, i.e. the sender can proof that he sent the data (Non-repudiation of the origin of the data) and the receiver can proof that he received the data (Non-repudiation of the receipt of the data). Traceability also covers the methods used to store and present document displacement on maps and floorplans. Also the methods for visualizing document movement among users.

4 Modeling Document Flow with Spread Page

Document flow modeling with Spread Page principles gives some tangible benefits. Thanks to the techniques described in previous chapters the model can be more readable and detailed. The Table 1 below describes how different Spread Page representations can be used in order to model document flow.

For business process diagramming the scaled-detail representation can be user. It helps to present on a single diagram both the general view on the process and its detailed view. That approach helps to understand processes and gives the ability to switch into details without losing the context of the process part being analyzed.

Aspect oriented representation is also helpful with business process diagramming. Thanks to that kind of multidimensional diagrams a process designer can focus himself

Table 1. Modeling document flow with spread page

Document flow modeling aspects \ Spread Page model representations	Three-dimensional	Time-varying	Layered	Scaled Detail	Aspect-oriented
Business process diagram				X	X
Meta-data model		X	X		X
Storage and location model	X			X	
Filing model	X				
Document content					X
Versioning		X			
Traceability	X	X		X	

on the given aspect of the model, having its other aspects hidden as far as they are not important on that stage of analysis.

For meta-data modeling time-varying and layered representations are useful to show historical changes of data model. In addition, the aspect oriented representation together with the layered representation can be used to determine accessibility levels for different parts of document meta-data. That approach is also the only way to establish individual data optionality for each task in the business process model.

Three-dimensional representation is very useful for preparation of storage and location models as well as filing model. All of these models are of spatial character. Thanks to the three-dimensional modeling the real-world locations can be reflected in a natural way.

Because of hierarchical arrangement of the storage units, the scaled detail representation is also used for the storage and location model. Thanks to that, operations like drill-down and roll-up are possible to perform.

A document content must not be the same for different groups of readers. Each of them could be interested in different part of the document and could look at it from different angles. That’s why the aspect-oriented representation is best to adapt.

As far as versioning is nothing more than storing document changes in time, time-varying representation is the best option in that case.

Traceability refers to the three spatial dimensions and the time dimension. Therefore Three-dimensional representations, Time-varying representations, and Scaled detail representations are used to prepare adequate models.

5 Conclusion

The use of new possibilities of the Spread Page notation for knowledge representation, such as Three-dimensional Representation, Time-varying Representation, Layered Representation, Scaled Detail Representation, Aspect-oriented Representation to describe metadata and the dynamics of displacement of documents in the restricted access administrative office was discussed and described.

The research results are part of a R&D project partially supported by the National Centre for Research and Development under grant No. DOBR-BIO4/006/13143/2013.

The science project – entitled "Electronic system for life-cycle management of documents with various level of confidentiality" – focuses on the use of the latest information and communication technologies related to Radio-Frequency Identification (RFID) and biometrics. The aim of completing this research project is to build and implement a prototype of a modern secret office designed to manage documents with various levels of confidentiality. The project covers all processes that take place in a secret office and use devices equipped with RFID transmitter /receiver modules.

The project tasks, especially those related to the design, demonstrated the usefulness of the Spread Page approach to document management design and implementation.

References

1. Waszkowski, R., Tarnawski, T.: Spread page initiative. http://spreadpage.org/spreadpageinitiative.pdf. Accessed 30 Sept 2015
2. Butlewski, M.: Practical approaches in the design of everyday objects for the elderly. In: Slatineanu, L., Merticaru, V., Nagit, G., et al. (eds.) Innovative Manufacturing Engineering Conference (IManE) Location, Chisinau, Moldova, 29–30 May 2014. Engineering Solutions and Technologies in Manufacturing Applied Mechanics and Materials, vol. 657, pp. 1061–1065 (2014)
3. Jasiulewicz-Kaczmarek, M., Saniuk, A., Nowicki, T.: The maintenance management in the macro-ergonomics context. In: Goossens, R.H.M. (ed.) Advances in Social & Occupational Ergonomics Proceedings of the AHFE2016 Conference on Social & Occupational Ergonomics, 27–31 July. Advances in Intelligent Systems and Computing, vol. 487, pp. 35–46. Walt Disney World®, Florida, USA (2016)
4. Burduk, A.: The role of artificial neural network models in ensuring the stability of systems. In: 10th International Conference on Soft Computing Models in Industrial and Environmental Applications. Advances in Intelligent Systems and Computing, vol. 368, pp. 427–437 (2015)
5. Butlewski, M., Slawinska, M., Niedzwiecki, M.: 3D laser models for the ergonomic assessment of the working environment. In: Goossens, R.H.M. (ed.) 7th International Conference on Applied Human Factors and Ergonomics (AHFE) / International Conference on Social and Occupational Ergonomics, 27–31 July 2016. Advances in Social & Occupational Ergonomics. Advances in Intelligent Systems and Computing, vol. 487, pp. 5–23. Walt Disney World, Bay Lake (2017)
6. Jasiulewicz-Kaczmarek, M.: The role of ergonomics in implementation of the social aspect of sustainability, illustrated with the example of maintenance. In: Arezes, P., Baptista, J.S.,

Barroso, M., Carneiro, P., Lamb, P., Costa, N., Melo, R., Miguel, A.S., Perestrelo, G. (eds.) Occupational Safety and Hygiene, pp. 47–52. CRC Press, Taylor & Francis, London (2013)

7. Cartwright, N.: How the Laws of Physics Lie. Oxford University Press (1983)
8. Hacking, I.: Representing and Intervening. Introductory Topics in the Philosophy of Natural Science. Cambridge University Press, Cambridge (1983)
9. 3D Scanning Advancements in Medical Science, Konica, Minolta. http://sensing.konicaminolta.us/application_notes/3D-Scanning/Applications-In-Medical-Science. Accessed 24 Oct 2011
10. Wehmuth, K.: A unifying model for representing time-varying graphs. In: Proceedings of the IEEE International Conference on Data Science and Advanced Analytics (IEEE DSAA 2015) (2005). https://arxiv.org/abs/1402.3488
11. Navigation device assisting road traffic congestion management. FreshPatents.com, 9 March 2007. http://www.freshpatents.com/Navigation-device-assisting-road-traffic-congestion-management-dt20080925ptan20080234921.php. Accessed 12 Oct 2008
12. Husby, J.: In-car navigation matures beyond 'Point A to Point B'. Electron. Eng. Times, 28 January 2008. http://www.automotivedesignline.com. Accessed 12 Oct 2008
13. Frank, A.U., Timpf, S.: Multiple representations for cartographic objects in a multi-scale tree - an intelligent graphical zoom. In: Computers and Graphics. Special Issue on Modelling and Visualization of Spatial Data in GIS, vol. 18, no. 6, pp. 823–829 (1994)
14. What Is Document Management? Microsoft Developer Network. https://msdn.microsoft.com/en-us/library/dd163514.aspx. Accessed 28 Feb 2017
15. KBsT - Federal Government Co-ordination and Advisory Agency. SAGA - Standards and Architectures for eGoverment-Applications, version 2.1, Schriftenreihe der KBSt 82 (2005a)
16. KBsT - Federal Government Co-ordination and Advisory Agency. DOMEA concept. Document Management and Electronic Archiving in Electronic Courses of Business, Organisational Concept 2.0, Schriftenreihe der KBSt 74 (2005b)
17. Ritchey, T.: Outline for a morphology of modelling methods: contribution to a general theory of modelling (2012)

Classified Document Flow Management

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Abstract. This paper describes the concept and system design of the classified document flow management module. It considers tracking and visualizing of on-premises and off-premises documents displacement. The requirements model connected with documents traceability as far as the methods of documents tracking visualization were developed and presented in this paper.

Keywords: Document management · Systems engineering · Classified documents · Document tracking · Visualization · Aurea BPM

1 Introduction

The offices of modern enterprises are equipped with hardware and software to effectively manage open and classified documents. Complementing the currently used solutions with the opportunity to identify each document using the RFID tags makes it possible to obtain an automated document management system. It offers great opportunities in the field of document security, accountability and traceability.

The basic functionalities of the system include:

- remote identification of unclassified and classified data storage devices labelled for real-time radio-reading at the storage and work location;
- automatic inventory of unclassified and classified documents arranged in piles and filed, including automatic detection of relocation;
- control of the movement of data storage devices as well as unclassified and classified documents across security zones, including access control of unclassified and classified documents;
- protection of data storage devices and documents against unauthorized relocation;
- automatic identification of data storage devices and documents not only at the storage location, but also at workstations;
- protection against repeated copying of unclassified and classified documents;
- control of printing of unclassified and classified documents with a copy limit;
- identification of the location of individual unclassified and classified documents with a pre-set accuracy of a file or volume location.

This paper describes the concept and system design of the classified document flow management module. It considers tracking and visualizing of on-premises and off-premises document displacement. In addition, the methods of document tracking visualization were developed and presented in the document.

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The research results are part of an R&D project, partially supported by the National Centre for Research and Development under grant No. DOBR-BIO4/006/13143/2013, entitled "Electronic system for life-cycle management of documents of various level of confidentiality" – focuses on the use of the latest information and communication technologies related to Radio-Frequency Identification (RFID) and biometrics. The aim of completing this research project is to build and implement a prototype of a modern secret office designed to manage documents of various levels of confidentiality. The project covers all processes that take place in a secret office and the use of devices equipped with the RFID transmitter/receiver modules. The focus of the research is not only on documents and data carriers, but also on all secret office equipment (cabinets, desk, copying machines and entry/exit control devices) and appropriate software (the RFIDoc system).

2 Classified Document Flow Management System Architecture

The document lifecycle management, built on the basis of the Business Process Management System, is used by the personnel of the restricted access administrative office, where the system is to be implemented. The system co-operates with the following external systems: CrossTalkAppCenter and Cosmos. It is integrated via adequate programming interfaces (Web Service). The document flow management system also has a graphic user interface (GUI) accessible from an Internet Browser. CrossTalkAppCenter and Cosmos also have user interfaces enabling their control and configuration (Fig. 1).

The system is also equipped with a variety of interfaces to external devices. These devices include: sluice, cabinet, copier, tray reader, and workstation. Each of the devices is equipped with RFID antenna. It gives the possibility to check for the presence of documents in the range of devices' antennas [1–3].

The use of RFID tags and antenna readers allows you to maintain all the events that can occur during the completion of every-day work. These events, stored in the database, are a very good source for further data analysis in terms of document tracking. Thanks to the workflow module that is the part of the system architecture, it is possible to plan how documents moves between all participants of business processes related to a modern restricted access administrative office [4, 5].

To enter the secret office, it is necessary to go through a sluice (Fig. 2, left). The sluice is composed of the entrance door, which allow to enter the secret office from its environment, and exit door, which allow to exit the secret office to its environment.

It provides the functionality of RFID document detection as well as metal detection. All the information obtained during the scan may be used to initialize further archive procedures, such as limiting access to certain parts of the building, informing the security personnel and so forth.

The cabinet (Fig. 2, right) is an independent mechanically-electronic storage unit. It has been designed to automatically detect all documents stored within it. This is achieved with the HF RFID Mode 2 ISO 18000-3 tags.

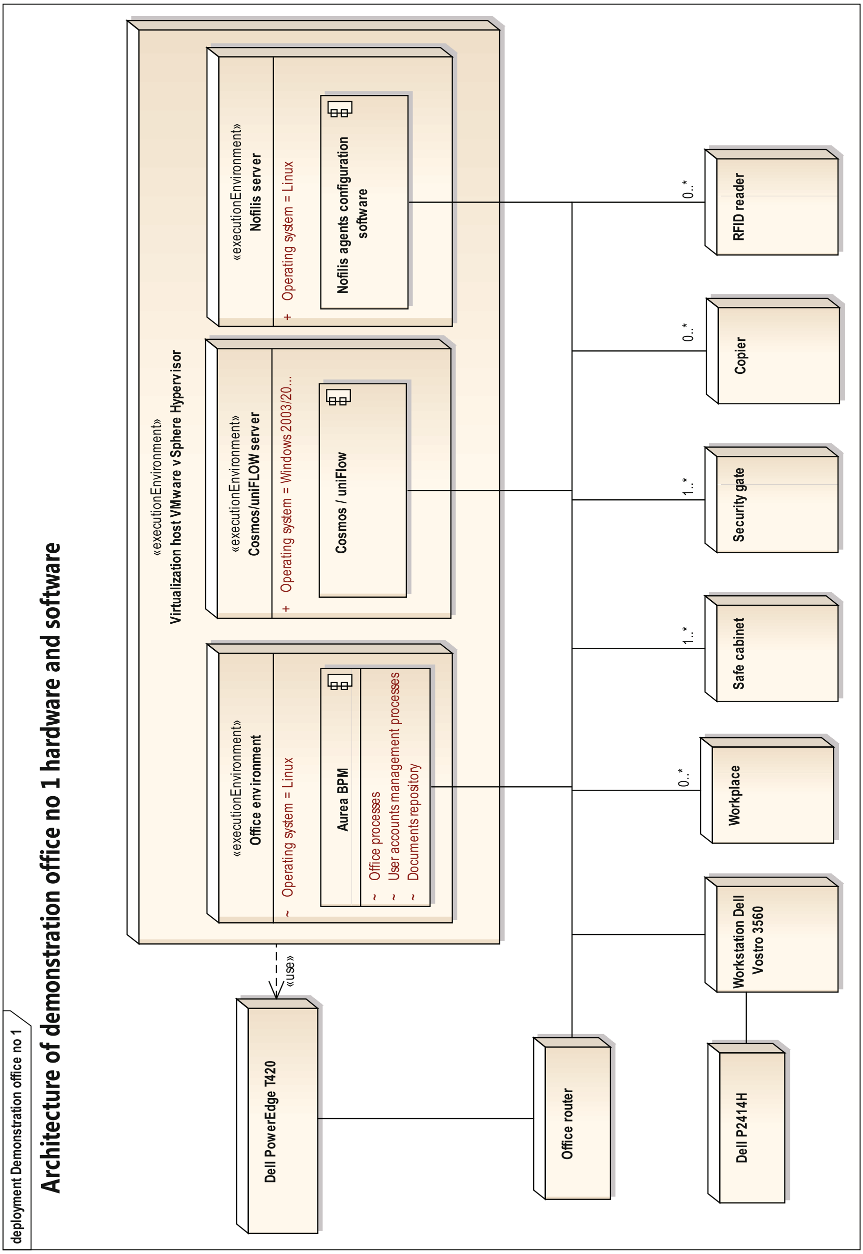

Fig. 1. System architecture. Source: own elaboration

Fig. 2. The entrance sluice/body scanner (on the left) and the cabinet (on the right)

The cabinet casing is made of coated wood or metal, depending on the model. A pair of sliding door is installed in each, with both a physical and a magnetic lock on it. Aside from the casing, the cabinet contains the RFID infrastructure (the reader and the internal antennas), as well as a control unit, a power supply unit, the main board and the electromagnetic lock which is unlocked with an identifier RFID tag.

The administrative office is also equipped with a copier (Fig. 3, left). This device is based on Canon 4225 copier machine. It synchronizes the process of copying of the document with the RFID tag readout of both the document and the RFID identifier of the user.

Based on the information read from the tags the centralized archive system permits the copier to create physical copies of only those scanned documents for which the user is authorized.

The copier includes a purposefully designed RFID antenna, a RFID reader and a server station modified to interface with the centralized archive system.

The tray reader (Fig. 3, right) was designed for the purpose of initial document registration. It automatically identifies, reads, writes and tracks the RFID-tagged documents. It is capable of reliable readout and writing of all RFID tags of the documents placed on the covered part of the tray.

Fig. 3. The RFID copier (on the left) and the tray reader (on the right)

Tightly packed stacks of overlapping or touching RFID tags are identified with 100% reliability. The reader operates instantly thanks to two reply channels and is capable of reliably identifying up to 60 documents placed in the tray [6–10].

The workstation for the restrictive access administrative office workers is equipped with desktop computer connected to all necessary peripheral devices including tray readers. It is also equipped with appropriate software for document management and business processes execution (Fig. 4).

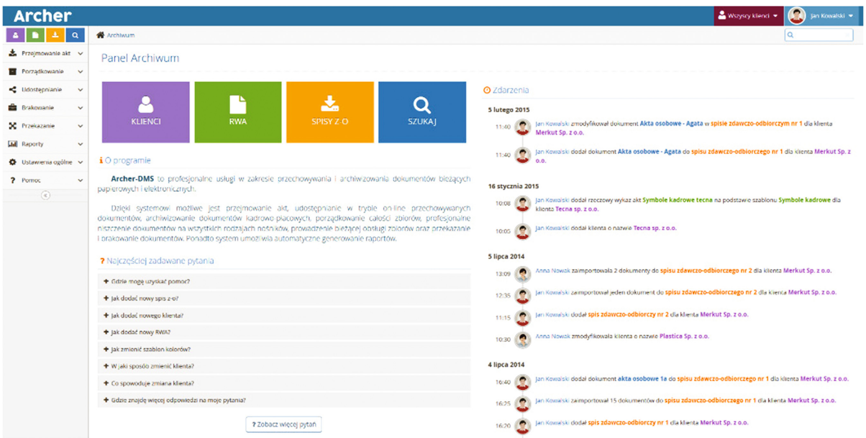

Fig. 4. The restrictive access administrative office management system

3 Tracking and Visualizing of Document Displacement

As a result of the analysis carried out in order to design a document displacement visualization module, the following basic features were set out:

1. Create a storage hierarchy for keeping classified documents.
2. Provide the ability to specify the layers for storage units in the store.
3. Maintain data about the storage units.
4. Assign the documents to storage units.
5. Create a hierarchy of documents.
6. Specify the location for the storage unit.
7. Specify the location of the document.
8. Store data about the document.
9. Maintain document change history and document location history.
10. View the history of a document displacement on the map.
11. View the history of a document displacement as a list.
12. Provide a search functionality for data about the document or the storage unit throughout the system.
13. Display search results as a list.
14. Display search results on the map.

As the result of design stage the requirements model for the document displacement visualization module was prepared. The exact characteristics of each of the requirements are presented in Table 1.

Table 1. Requirements specification for the document displacement visualization module. Source: own elaboration

Requirement name	Requirement description
FR-001 Visualization module	The Visualization Module is one of the components of the RFIDoc visualizer is one of the components of the system rfiDoc and is responsible for the visualization of the movement of documents with different levels of sensitivity
FR-002 RFID ID Registration	The module allows registering RFID for documents stored in the Office and for users of the system with RFID ID card
FR-003 Registration ID RFID for the document	The module allows the registration of RFID identifier for a document stored in the Office. The designation of the RFID ID document allows you to the location of the movement document between zones
FR-004 Registration ID RFID for the user of the system	The module allows the registration of RFID identifier for the system user. The RFID ID's for employees of the law firm to work with RFID devices. Work with RFID devices is dependent on the permissions assigned on the user

(*continued*)

Table 1. (*continued*)

Requirement name	Requirement description
FR-005 Assigning geographic location	The module allows you to specify the geographic location for documents and inventory units registered in the system rfiDoc
FR-006 Assigning geographic location for the document	The module allows you to specify the geographic location for the document. The document commonly takes geographical assigned the inventory unit in which it is stored
FR-007 Assigning geographic location for SKU	The module allows you to assign geographical location for the SKU. Adding to the geographical influences on subsequent renderings of units on the map. Geographical units also applies to documents that are marked as child elements relative to the unit
FR-008 Add storage structure model for storing documents	The module allows you to add a storage structure for storing documents with different levels of sensitivity. In Windows it is possible to add the entire storage hierarchy starting with on the building and on a single document
FR-009 Adding structure using automatic storage Wizard	The module allows you to add storage structure using a special Wizard that automatically creates the structure of the whole warehouse in accordance with the fundamental values specified by the user
FR-010 Adding individual elements of storage structure	The module allows you to add individual SKUs within the structure. User of the system I have the ability to manually modify the SKU and create storage structure without using a wizard
FR-011 a mechanism to create a hierarchy of documents	The module allows you to create within the structure of the hierarchy store inventory units and hierarchy of documents
FR-012 mechanism for adding layers on the map	The module has a built-in mechanism for adding layers on the map
FR-013 add layers for storage units	The module allows you to add layers for the SKUs. Each added layer is visible on the map
FR-014 Edit layers for SKU	The module enables you to edit already added layers for the SKU
FR-015 Removing layers for SKU	The module allows you to remove the layers added for SKU. Removed layer will not be visible on the map
FR-016 search documents and inventory units in the system	The module allows you to search all the data contained in the system m.in. documents and inventory units
FR-017 to display the search results on a map	The module allows you to display the search results data in the system on the map. Display the search item in the form of graphics on the map, is possible only if the specified will be the location of the item

(*continued*)

Table 1. (*continued*)

Requirement name	Requirement description
FR-018 to display the search results in a list	The module allows you to display the search results in the form of a list. Display the search results in the form of a list is not dependent on the assignment location in the system
FR-019 collect and store the document history	The module allows the collection of data on the history of a single document. History of the document is displayed in graphical form or by using the list
FR-020 displaying results graphically on a map	The module allows you to view the history in the form of graphics on the map. On the map are marked with points symbolizing the storage location of the document and points symbolizing where the document and where it was sent for the case when the document is in the process of movement
FR-021 viewing results in the form of a list	The module allows you to view the history of a single document in the form of a list of events performed on the document. The story consists of items illustrating the activities related to the editing document data or with his movement
FR-022 Visualization on a map	The module allows a Visual representation of the location of an element registered in the system on the map
FR-023 visualization of position documents on a map	The module allows a Visual representation of the location of the document on the map. Taking into account the changes in the position of the path of the document
FR-024 Visualize the position of inventory units on the map	The module allows a Visual representation of the location of the SKU on the map
FR-025 to track changes in the position of the	A Visualizer allows you to track changes in the position of the document on the maps

4 Document Tracking Visualization

The visualization module of the rfiDoc System presents the graphical and text history of a given document. Thanks to that there is the ability to track the path of the document displacement (Fig. 5).

RfiDoc system allows you to visualize the event handling of documents with different levels of sensitivity. To see the document events, go to the section: files and select documents [11–13]. Then it is possible to select the document whose events you want to see and select button: show document events document displacement history (Fig. 6). On the left appears the event visualization on the map, and on the right side of the timeline of events documents [14–16].

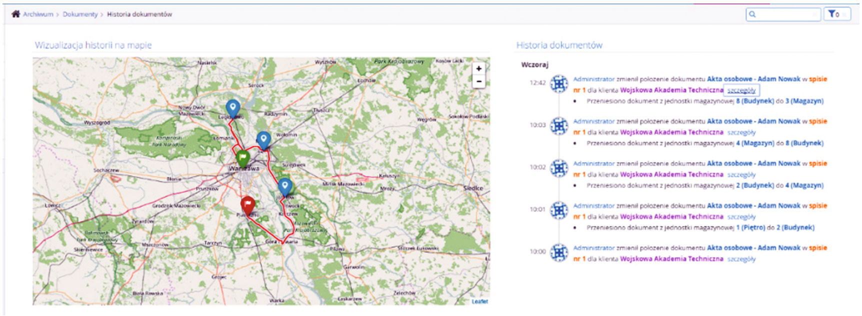

Fig. 5. Document tracking

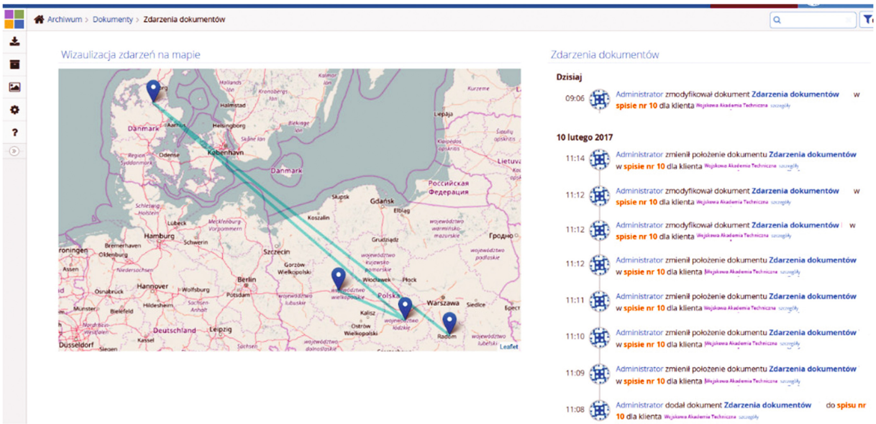

Fig. 6. Document displacement history

5 Conclusion

The research results are part of a R&D project partially supported by the National Centre for Research and Development under grant No. DOBR-BIO4/006/13143/2013.

The science project – entitled “Electronic system for life-cycle management of documents with various level of confidentiality” – focuses on the use of the latest information and communication technologies related to Radio-Frequency Identifica-tion (RFID) and biometrics. The aim of completing this research project is to build and implement a prototype of a modern secret office designed to manage documents with various levels of confidentiality. The project covers all processes that take place in a secret office and use devices equipped with RFID transmitter/receiver modules.

This paper describes the document flow management system design. Tracking and visualizing of document displacement are the most important features in terms of managing document security. The methods described above have been used in the Electronic system for life-cycle management of documents of various level of confidentiality (RFIDoc) developed by the consortium as the part of the project mentioned in the Introduction.

References

1. Robert, W., Maciej, K., Tadeusz, N., Zbigniew, W., Kazimierz, W., Mastorakis, N. et al.: Business processes in the RFID-equipped restricted access administrative office. In: MATEC Web Conferences, vol. 76, p. 4003 (2016). doi:10.1051/matecconf/20167604003
2. Robert, W., Agata, C., Maciej, K., Tadeusz, N., Zbigniew, W., Kazimierz, W. et al.: Data flow between RFID devices in a modern restricted access administrative office. In: MATEC Web Conferences, vol. 76, p. 4004 (2016). doi:10.1051/matecconf/20167604004
3. Kiedrowicz, M., Nowicki, T., Waszkowski, R., Wesołowski, Z., Worwa, K., Mastorakis, N. et al.: Software simulator for property investigation of document management system with RFID tags. In: MATEC Web Conferences, vol. 76, p. 4012 (2016). doi:10.1051/matecconf/20167604012
4. Kiedrowicz, M., Nowicki, T., Waszkowski, R., Wesołowski, Z., Worwa, K., Mastorakis, N. et al.: Method for assessing software reliability of the document management system using the RFID technology. In: MATEC Web Conferences, vol. 76, p. 4009 (2016). doi:10.1051/matecconf/20167604009
5. Kiedrowicz, M., Nowicki, T., Waszkowski, R., Wesołowski, Z., Worwa, K., Mastorakis, N. et al.: Optimization of the document placement in the RFID cabinet. In: MATEC Web Conferences, vol. 76, p. 2001 (2016). DOI:10.1051/matecconf/20167602001
6. Finkenzeller, K.: RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification, 2nd edn. Wiley, New York (2003)
7. Cole, P.H., Ranasinghe, D.C.: Networked RFID Systems and Lightweight Cryptography. Springer, Heidelberg (2008)
8. Zhang, Y., Yang, L.T., Chen, J.: RFID and Sensor Networks Architectures, Protocols, Security and Integrations. CRC Press, Boca Raton (2009)
9. Paret, D.: RFID at Ultra and Super High Frequencies: Theory and Application. Wiley, Chichester (2009)
10. Bolic, M., Simplot-Ryl, D., Stojmenovic, I.: RFID Systems Research Trends and Challenges. Wiley, Hoboken (2010)
11. Miles, S.B., Sarma, S.E., Williams, J.R.: RFID Technology and Applications. Cambridge University Press, New York (2008)
12. noFilis “CrossTalk AppCenter 3.0 Installation and Administration Guide”
13. Canon UniFLOW documentation - www.canon.com
14. Aurea BPM system documentation - aurea-bpm.com
15. Braude, E.J., Bernstein, M.E.: Software Engineering: Modern Approaches. Wiley, Hoboken (2011)
16. Larman, C.: Applying UML and Patterns: An Introduction to Object-Oriented Analysis and Design and Iterative Development, 3/e, Pearson Education India (2012)

The Use of IT Technologies in the Development of Employees

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Abstract. The success of an enterprise depends on efficient management of human capital. However, the application and use of IT solutions supporting human resource management in practice is still insufficient. The article consists of four parts: preliminary observations, theoretical issues concerning problems of human resource management, an analysis of statistical data from companies and concluding remarks. The first part, preliminary remarks, draws our attention to the fact that organizations wishing to maintain a good market position in tough economic times should be focused on continuous improvement of their employees. Only a modern enterprise where knowledge management plays a leading role can survive and be competitive. The second chapter analyzes the literature related to the management of human capital in organizations. The third chapter analyzes statistical data from Polish companies related to the use of IT tools aimed at the development of employees. The article summary includes closing observations based on research conclusions.

Keywords: Competences · Manager · Management · Knowledge · Skills · Attitudes

1 Preliminary Observations

In the face of extensive transformations which take place in the external environment of organizations, and most of all transformations caused by informatization, globalization and tightening competition, questions regarding employee development started to play an important role in human resource management and the process of shaping performance of businesses. This results from the fact that one of the greatest values for enterprises, regardless their location in the world, are their employees[1]. According to the market research, human capital determines the success of an enterprise. Openness, talent, innovativeness, hunger for knowledge and the ability which helps a company's employees adapt to the changing environment make companies gain or lose their value [1].

[1] Research conducted by organizations such as: McKinsey, General Electric and Procter & Gamble.

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According to managers, HR management expenses constitute on average between 40 and 60% of all costs incurred by an organization. This is why an efficiently operating HR department which supports employee development plays such an important role in an organization. A properly functioning HR department may indirectly affect the deployment of organizational priorities, directly affect goals of individual employees and to what extent they will be able to reach their business goals, and in turn, generate better results for the company.

Recently, we can observe the increased importance of HR departments in companies which move away from their basic organizational role, which comes down to dealing with payments and employee paperwork, to building advanced payment, training, career planning, and talent management systems. Such activities facilitate the best possible conditions for employee development.

Effective management of a modern HR department is highly complicated and often requires implementing advanced tools and solutions which help sort out large amounts of data. Therefore, it seems to be a good idea to implement cutting-edge IT solutions which will support the management process. It is especially important if we take into account the dynamics with which the concept of an employee career is constantly changing.

Consequently, the objective of this paper was to verify the use of IT technologies in employee development by modern organizations. In order to achieve the listed above goal, a research problem has been defined, namely: Do modern organizations which implement integrated management systems make the most of IT tools for better management of their human resources?

2 Human Capital Management in Organizations

The literature dealing with the subject matter emphasizes the significance of human capital as one of fundamental resources which plays a crucial role in social and economic development. In the opinion of D. Kopycińska, the fundamental factors which shape human capital include [2]: science, education, labor market, modern technologies, and health.

Human capital has various definitions and the variables which are used to describe it characterize resources on many levels. Basic elements which make up human capital are first of all: competences, intellectual dexterity, and motivation. This definition makes it possible to diagnose human capital quite precisely. Although the variables are few, they allow a comprehensive description of an enterprise's capital.

According to the definition by M. Bratnicki and J. Strużyna [3], human capital includes the following variables: competences, intellectual dexterity, and motivations which for example comprise talents, theoretical knowledge, resourcefulness, ability to change, and predispositions. The authors see human capital as an added value thanks to which an organization operating in a knowledge-based economy becomes more competitive.

The theory of M. Bratnicki and J. Strużyna on human capital originated in the 1960s in works of T.W. Schulz [4], *the winner of the 1979 Nobel Prize in economics, and M. Blaug* [5]. Works of these researchers discussed the impact of human capital on economic growth of a country and the capital value estimation. Based on the conducted studies, T.W. Schulz proved a strong link between the growth of GNP [6] and the level of a nation's education.

Based on his research, T.W. Schulz proved that there is a strong link between the growth of GNP and the nation's education level. When defining the crux of human capital, he presumed that all skills (present day competences) are either inherent or acquired. All people are born with a specific set of genes which determine their inherent abilities, or talents. The acquired qualities of a population, which are valuable and can be augmented by appropriate investment, constitute human capital [7].

Similarly to the definition by T.W. Schulz and M. Blaug, the definition of human capital by N. Bontis also linked human capital to knowledge, education, and individual skills (competences) of individuals in realizing national goals and tasks [8]. According to this definition, it can be assumed that human capital is made up of people and their competencies, that is all qualities and predispositions which are hidden in them, such as: knowledge, attitudes, and skills. Competencies have a specific value and constitute a source of future income for an entire organization [9].

The review of related literature shows that investment in human capital may bring measurable profits to the company [10]. Empirical research, which employed differed methodologies, proved that there is a link between the human capital of an enterprise and its financial performance. The results of 23 analysis conducted by J.D. Margolis and J.P Walsh indicate that there is a correlation between the level of human capital and the results achieved by an enterprise [11]. Also G. Urbaniak noticed that human capital is an added value for a company. He claimed that this value can be perceived in two ways:

– firstly, by direct application of knowledge and abilities of employees in economic processes, e.g. negotiations, implementation of operations (results of such operations transfer to revenues and lowering of costs, which is directly reflected in the company's profit and loss account),
– secondly, by accumulation of knowledge in intangible assets, enhancing their value (such value is not always directly reflected in financial statements; however it is externalized in the value increase of off-balance sheet intangible assets) [12].

Nevertheless, it is difficult to unequivocally measure human capital in organizations and clearly determine benefits which are connected with it.

It also appears necessary to take into consideration the division by M. Bratnicki and J. Strużyna where employees' talents constitute a particularly important component of human capital which can guarantee a competitive advantage to an organization [13]. According to the definition by K. Głowacka-Stewart, a talented organization member is capable of fulfilling higher functions within an organization, has potential for further development, and his/her work increases a company's value [14]. This is why identifying talents, introducing talent management enhancement programs, motivating talented individuals and demonstrating relationships between effective talent management and benefits resulting from it are crucial elements in the management of an organization [15]. The ultimate objective for introducing programs supporting talent management in companies is building competitive advantage. Regardless of the company's economic situation and market position, it is the knowledge of employees, and most of all their creative thinking, that moves each company operating in a dynamically changing environment to a prominent position. Additionally, providing care to above-average employees becomes a motivator for other participants in the organization, activating their self-improvement.

It also needs to be noted that more than half of employers' representatives (58%) claimed that their companies have formal talent management strategies. In the case of companies with more than 5000 employees the percentage is 82%, in companies with the number of employees between 1000 and 4999 – 57%, and in companies with less than 1000 employees – 55%[2].

3 Using IT Tools to Support HR Management

For many years it was believed that proper human capital management affects employee development but nobody connected it with the business success of an organization. Over time, thanks to the market research, companies changed their way of viewing people management which unequivocally indicated that it was thanks to properly implemented people management strategies that organizations gained competitive advantage in the market [16], created their positive image, and improved economic results. It was self-evident that a modern IT system supported implementation of such strategies.

The purpose of this article is to verify the actual usage of IT technologies in employee development by modern organizations. In order to achieve this purpose, we examined twenty companies employing over 50 workers. The study included IT organizations which sell cutting-edge solutions supporting business management. The companies have been operating in the Polish market for less than 20 years, so they qualify as "young" companies (Fig. 1). Only three of them have been in business for sixteen years.

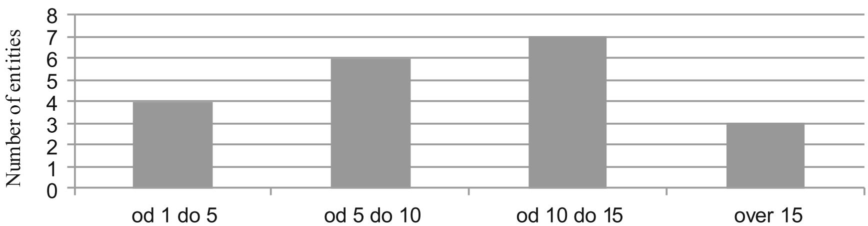

Fig. 1. Number of years in the Polish market. Source: developed by authors, based on studies

[2] Study executed by ADP Research Institute in August 2011 among HR professionals from 602 American organizations employing at least 500 employees.

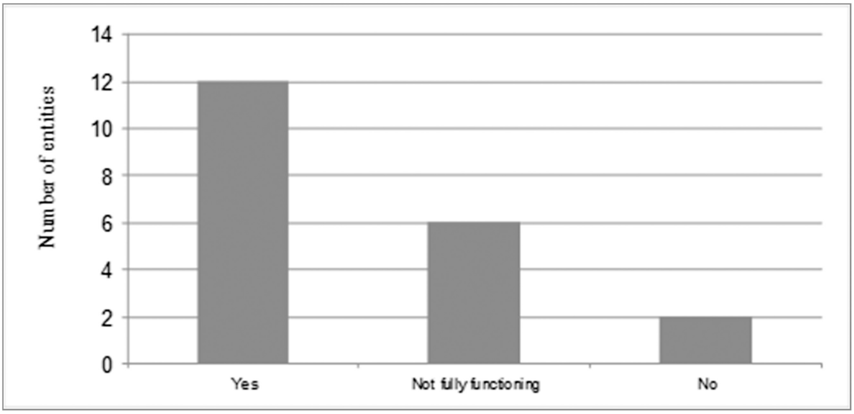

Fig. 2. Organizationally separate HR department. Source: developed by authors, based on studies

Most of the studied companies have a separate HR department (Fig. 2). However, some of their managers claimed that the departments are not fully operational, and even have certain flaws which disorganize work in the department. Employees were not always assigned specific duties and that is why they did not know what they were held accountable for.

One of key questions the managers in the studied organizations were asked regarded the use of IT management support systems. Majority of the studied companies implemented such a system; however, not in all departments (Fig. 3). It was mostly used by the accounting, IT, and sales departments, and usually limited to managing figures and not people to support their development. Although the studied companies are considered most modern in Poland and selling people management modules, they did not use such solutions in their own companies.

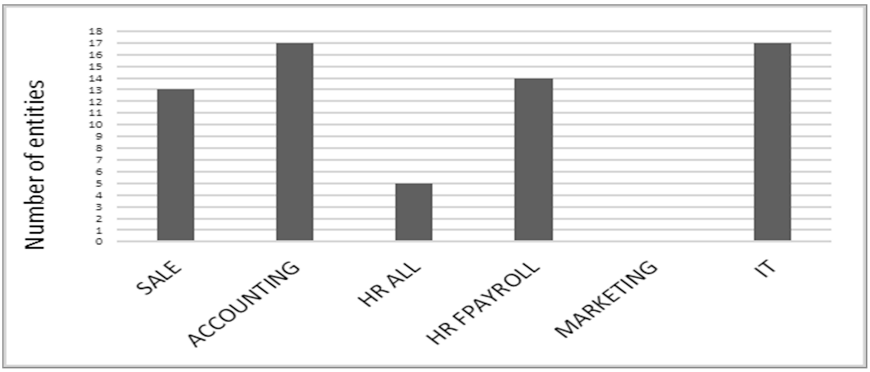

Fig. 3. Departments within organizations with implemented IT systems. Source: developed by authors, based on studies

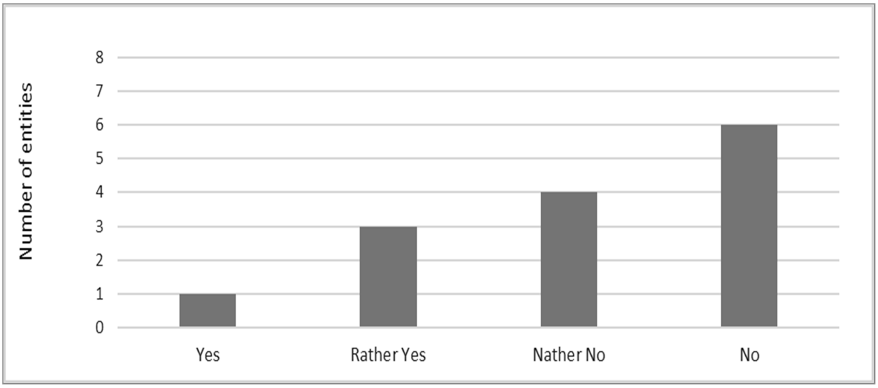

Fig. 4. Development needs acknowledged by HR. Source: developed by authors, based on studies

Even if the companies did make certain efforts to install an HR system, it turned out that it was used for calculating payments, annual or sick leave. Managers in 4 organizations only stated that the IT system was fully functioning in an HR department.

Four of the studied companies (Fig. 4) included employee's development needs in their IT systems. It comes as a surprise, especially since the companies belong to the group where up-to-date knowledge plays such a crucial role.

An efficiently operating IT system supporting people management in an organization allows designing particular stages of an employee support program. Properly implemented IT tools shorten the time needed for verification of paperwork collected to identify needs of participants within an organization. Moreover, the IT system allows the superiors to access detailed job descriptions and specific information regarding particular employees. It also gives access to the data about expectations of employees in certain positions which should correspond with their competencies. Acquired information is automatically generated by the system and in a simple and adequate way transferred to the person concerned. If the system detects any competence deficiencies, the superior receives feedback which can be used to plan employee development. The system makes it possible to assign tasks which result from the company's strategy, but also allows the organization participants to improve according to their expectations. Additionally, it enables assessment of the execution of adopted assumptions and, depending on the achieved results, employees are awarded a bonus or are instructed to improve their results by undergoing training. The advantage resulting from the application of IT systems is a shorter time of accessing desired information which allows making comparisons and statements, and lowers costs of many processes [17].

Unfortunately, only six of the studied organizations (Fig. 5) took into consideration actual training needs resulting from earlier conducted analyses. It was usually the employees themselves who informed employers about their training needs, which not always turned out to be justifiable.

The results were even worse when it comes to the needs of talented persons in an organization (Fig. 6). The module supporting needs of exceptional people worked only

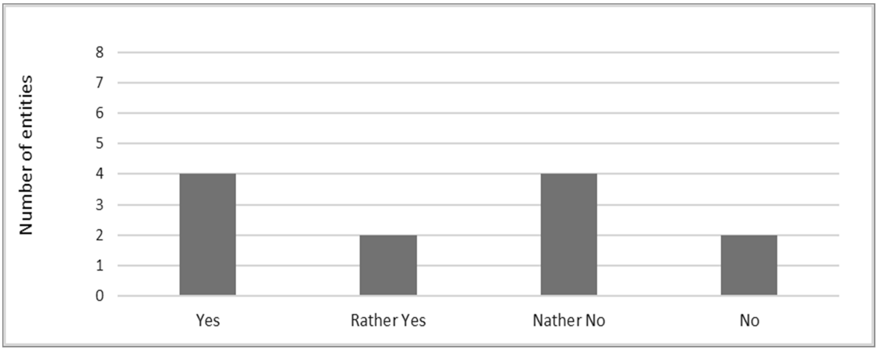

Fig. 5. Training needs acknowledged by HR. Source: developed by authors, based on studies

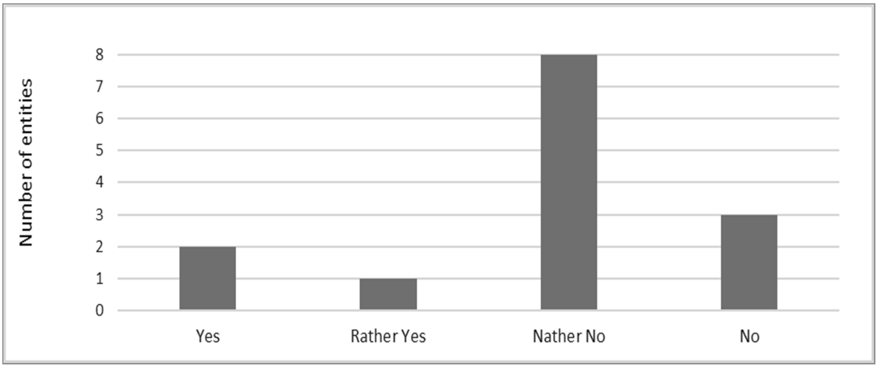

Fig. 6. Needs of talented employees acknowledged by HR. Source: developed by authors, based on studies

in the case of three companies. It is very surprising, since the studied organizations build their market position thanks to outstanding employees whose knowledge guarantees their company's competitive advantage.

Although the concept of talent management is still quite new in Poland [13], it is more and more often becoming a key element of HR strategies in many modern companies. It does not only help organizations build their positive image, but most of all it helps them improve results.

4 Conclusions

The principle goal of human capital management in organizations is not only increasing competence level in employees, but most of all building strong relationships between the employed and the company. Such approach makes organization participants feel appreciated and change jobs less frequently. Retaining valuable employees is one of priorities of organizations these days, and is often listed as a strategic goal. One of the tools supporting people management process is an efficiently operating IT system which facilitates employee career planning and their multilevel development. Properly implemented IT tools significantly shorten the time needed for verification of personal paperwork and at the same time show necessary and required training programs. This operation facilitates and speeds up estimation of the budget necessary for training implementation, and minimizes inter-organizational costs.

Based on the achieved results it can be concluded that the studied organizations, even though we call them modern, use IT tools to support human capital management only to a certain extent [18]. In most cases the system is used only to fulfill very basic HR functions without acknowledging development needs of employees. It can be concluded then that applying IT tools for employee development is a myth rather than a fact in these companies. Managers still do not fully realize the importance of development and progress of employees and the impact of these elements on the company's performance.

It needs to be underlined that thanks to the implementation of IT systems HR managers or immediate superiors can follow progress of improvement program participants and check whether the right persons have been included in such programs [1]. Because employee development is a challenge for managers as well as organizations [19], the efficient execution of plans connected with the development and allocation, but first of all, identification of talented employees is made possible thanks to HR department support IT tools.

Managers in large and modern organizations must then take into account the fact that without properly selected IT instruments organizations which operate in a rapidly changing business environment are not capable of comprehensive people management and increasing their chances to keep the most valuable employees whose presence makes the organization more competitive. Therefore, the use of cutting-edge IT solutions to manage people in organizations should become a fact and not only a utopian myth.

References

1. Rytelewska, A.: Nowoczesna narzędzia IT wspomagające zarządzanie talentami w organizacjach. Zeszyty Naukowe WSB **60**(3), 125–138 (2015)
2. Kopycińska, D.: Kapitał ludzki jako czynnik rozwoju społeczno-gospodarczego. Uniwersytet Szczeciński, Szczecin (2006)
3. Bratnicki, M., Strużyna, J.: Przedsiębiorczość i kapitał intelektualny, Wydawnictwo Akademii Ekonomicznej w Katowicach, Katowice (2001)
4. Schulz, T.W.: Investment in human capital. Am. Econ. Rev. **51**, 1–17 (1961). Juchnowicz, M. (ed.) Elastyczne zarządzanie kapitałem ludzkim w organizacji wiedzy, p. 15. Difin, Warszawa (2007)
5. Blaug, M.: Metodologia ekonomii. Wydawnictwo Naukowe PWN, Warszawa (1978)
6. Juchnowicz, M.: Elastyczne zarządzanie kapitałem ludzkim w organizacji wiedzy. Delfin, Warszawa (2007)

7. Schulz, T.W.: Investing in People: The Economics of Population Quality, pp. 12–17. University of California, Barkley (1981). Juchnowicz, M. (ed.) Elastyczne zarządzanie kapitałem ludzkim w organizacji wiedzy, p. 15. Difin, Warszawa (2007)
8. Bontis, N.: National intellectual capital index, a United Nations initiative for Arab regions. J. Intellect. Capital **5**(1), 13–39 (2004)
9. Francik, A.: Kreatywność – niedoceniany składnik wartości przedsiębiorstwa. In: Jabłoński, M. (ed.) Zarządzanie wartością przedsiębiorstwa WSB, Dąbrowa Górnicza, pp. 339–352 (2011)
10. Andrzejczak, A.: Ekonomizacja szkolenia pracowników jako czynnik wartości przedsiębiorstwa, pp. 46–61. UE, Poznań (2011)
11. Margolis, J., Walsh, J., Margolis, J.: People and Profits? The Search for a Link between a Company's Social and Financial Performance. Mahwah Erlbaum, New York (2001)
12. Urbanek, G.: Kompetencje a wartość przedsiębiorstwa, pp. 40–41. Wolters Kulwer business, Warszawa (2011)
13. Ingram, T.: Zarządzanie talentami. PWE, Warszawa (2011)
14. Głowacka-Stewart, K., Majcherczyk, M.: Raport badawczy E - 0011-06-RR, Zarządzanie talentami: Wyzwania, trendy, przykłady rozwiązań, p. 5. www.conferenceboard.org/pdf_free/report_zarzadzanieTalentami.pdf. Accessed 15 Dec 2016
15. Lawer III, E.E.: Strategic talent management: lessons from the corporate world. Strateg. Manag. Hum. Capital **5**, 1–35 (2008)
16. Pocztowski, A.: Zarządzanie talentami w organizacji. Oficyna Wolters Kulwer Polska, Warszawa (2008)
17. Tabor, A.J.: Zarządzanie talentami w przedsiębiorstwie. Poltext, Warszawa (2013)
18. Olszewski J.: System pracy w warunkach globalnego społeczeństwa informacyjnego, p. 71. Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu, Poznań (2013)
19. Miś, A.: Charakterystyka procesów rozwojowych pracowników utalentowanych. In: Pocztowski, A. (ed.) Zarządzanie talentami w organizacji, p. 136. Oficyna Wolters Kulwer Bussines, Kraków (2008)

Research Methods of Utility of Smartphones in Mobile Telecare

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Abstract. Promotion of the activity of elderly people with the telecare which uses smartphones is an author's proposal to increase accessibilities long term care outside their habitation. The article is a reply to the deficit of ergonomic methods appraisal of the usability smartphones for elderly people in the mobile telecare. Methods of estimation of the usability of mobile phones can't directly be applied to smartphones which interaction of users is with the help of the touch screen. In the first empirically verified research applied method of assessment utility smartphone HS in comparing with Nielsen's heuristics demonstrated more effective searching for problems with the service of the interface of operating system Android. Then was developed new method of indicator assessment of the usability smartphones based on heuristics HS, checklists and the environment of the evaluation of the usability of mobile phones. Method has an application potential, because it enables effective comparing smartphones with different operating systems in the aspect of their usefulness for elderly people.

Keywords: Ageing society · Long-term care · Smartphone · Usability · Heuristics Ergonomics · Telecare · Gerontechnology

1 Introduction

The article shows current and important gerontechnology topic in the area of interdisciplinary field of research that connects social gerontology with new technologies. Supporting the safety and independent living of the elderly people by ICT technologies should apply to all their activities, both in the home and mobile.

Currently, there is a lack of solutions in home telecare and mobile telecare that supports mobile activities outside the home. Because of the increasing universality, the best platform for telecare as a local social policy e-service is smartphone equipped with a touch screen and sensors. It facilitates the acceptance of ICT by older people, because it eliminates the need for peripherals devices such as a mouse, keyboard and monitor [1].

The increase of the usefulness of smartphones is a requirement for improving acceptance and using this devices in a mobile environment by older people. It was

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assumed that the higher usefulness of smartphones has a positive effect on the acceptance and utility by seniors.

The usefulness of smartphones has the effect of increasing the availability of telecare as a local social policy's e-services delivered as a part of long-term care [2]. Simultaneously, it was stated through the analysis of domestic and foreign literature the deficit of methods, theoretical models, parameters and indicators needed to empirical evaluation the usefulness of user's interfaces of smartphones that are used by elderly. In particular, the lack of method that could estimate the usefulness of smartphones by the viewpoint of elderly with limited functionality.

Because of the fact that the existing methods of measuring utility applications and the mobile phones are not fully adapted to evaluate the usefulness of smartphones, it is necessary to develop a comprehensive method that contains the theoretical model, criteria, checklists and indicators.

2 Heuristic's Method of Evaluation of the Smartphone's Utility

According to D.C. Burdick [3] gerontechnology at the micro level apply to interaction between gerontechnology and their users. At the micro level of gerontechnology there are many important interactions (such as sensual, perceptive, cognitive and motoric) with the user's devices by interface. Designing of the utility of the user's smartphone interface depends on the knowledge we have about the limitations of the elderly, the tasks they perform and interactions with the system during use.

Large touch screens improves the usefulness of smartphones, they allow you to zoom icons, adjustment of the contrast, they reduce the need for glasses [4].

Heuristics evaluation is a popular utility method of the user's interface that allows to recognize of the problems related to designation of user's interface.

The most commonly used heuristics, which are used in the study that includes usability of Nielsen's heuristics HN [5] developed in 1994 based on the earlier set of rules [6]. HN creates ten main principles of human interactions - a device that refer to elements such as visibility of system status, compliance between the system and the reality, standards of the behavior and consistency, prevent errors, and ensure their efficient service and support for the user.

Due to the different contexts of use and features of the smartphone, the evaluation of their utility is a difficult process and depends on:

- mobile context of use - all aspects related to user interaction, the system and the surrounding environment that occurs simultaneously,
- the size and resolution of the touch screen - a small screen and resolution can lead to usability issues,
- using small buttons for input the data and labels may reduce the effectiveness and efficiency in data entry (consequently, that reduces input speed and increases the number of errors in the process).

Heuristic analysis can identify problems related to the design of the user interface and deliver quickly and at relatively low cost feedback to designers. It can be used earlier in the software development process and the proper selection of heuristics can be helpful in rapid improvement of the functional quality of the interface.

The evaluation of the usefulness can be conducted without users by a few experts analysing and assessing the compliance of the interface with principles of the utility. Every evaluation is being carried out independently and the result is provided by the list of the potential problems associated with the utility. Correctly conducted gives the feedback to designers of the user interface and suggests specific changes increasing the utility. Tests of the utility are the method used for the evaluation of the utility of the user interface through the control group of future users. The purpose of the tests is to check in what way users deal the service of the system when performing typical tasks (behavior and interactions are being observed). In this method, to identify the problems associated with the utility, the data associated with the productivity of participants while examining is being analysed (task's execution time, rate of mistakes, number of mistakes, conversion, level of satisfaction with the performed objective), and a level of the satisfaction of participants from using operating systems is also being tested.

Due to the fact that traditional methods of measurement of the utility are not completely adapted to the evaluation of the smartphones, it was created a need for developing the new method of estimation of the utility based on the existing heuristic method.

It needs to be highlighted that the heuristic method destined to program the personal computers software is being a starting point for evaluation of operating systems of smartphones.

Depending on the situation, the result of the heuristic evaluation can be considered as an expert evaluation of the smartphone utility and as the ergonomic evaluation of the user interface.

The heuristic evaluation provides opinions about the user interface and helps identify problems of utility. Heuristics of the utility of Nielsen are often used as methods of estimation of the utility of software personal computers, application and websites.

In theory, it was developed the compartition of descriptions of heuristics of the utility of smartphone for elderly people with the heuristics of Nielsen. The Table 1 present an extensive evaluation of the heuristic (it was added the physical interaction HS11 and ergonomics HS12) for the smartphone with touch screen through the introduction of new heuristics HS1–HS12 for elderly based on the heuristics of Nielsen HN1–HN10.

The first examination consisted on the evaluation of the utility of popular smartphone with the touch screen (Samsung Galaxy Ace GT-S5830, operating system Android v. 2.3.3) was applied with heuristics described in Table 1.

S. Kurniawan' tests [8] showed that, in terms of using mobile phones the most important task for elderly, are: making and getting telephone, setting off the alarm, creating calendar reminder, change of the profile of the sound, sending and receiving text messages.

Therefore, the evaluation associated with the problems of usability made by six experts was carried out based on the performance of the eight most important tasks from the point of view of the elderly, which consisted of:

Table 1. Compartition of the heuristics of the utility of smartphones for elderly with the heuristics of Nielsen [7]

Heuristics of the utility of smartphone		Nielsen's heuristics of utility	
Identifier	Description	Identifier	Description
HS1	Visibility of the state of the system. The smartphone should inform the user of all the processes and changes through time feedback adapted to the user	HN1	Visibility of the state of the system The system should always inform the user about what is happening in a reasonable time
HS2	Adapt the system to the real world The smartphone should avoid technical terminology and communicate with the user by concepts known to him (in his language and using understandable analogies to reality). It is important to provide information in accordance with the natural order of reality	HN2	Adapt of the system to a real world The system should communicate with the user with his language and use understandable analogies to reality
HS3	Control and freedom to the user The smartphone should allow the user options for each operation: back, repeat, cancel and easy way out of an emergency situation. These options should be provided by a physical key	HN3	Control and freedom to the user The user must be able to deceive and undo an action in error There should be emergency exits like 'cancel' or 'back'
HS4	Consistency and standards The smartphone should be applied the consistently use the same words, symbols and actions, in accordance with accepted principles and standards (consistency: visual, operational)	HN4	Consistency and standards In the systemshould be applied consistent using the same words, symbols and action, in accordance with adopted principles and standards
HS5	Error Prevention The smartphone should hide or disable functions not available, should alert users of critical activities and provide access to additional information	HN5	Error Prevention System should prevent errors in first place, thanks to design that prevents the error from occurring
HS6	Identify rather than remember The smartphone should offer visible objects and navigation options, in order tomake smaller load of memory. User should not be imposed by memorizing information between successive stages of dialogue and operation; a guide should always be easily available	HN6	Identify rather than remember The user should not have to remember a hidden information in another screen. Similarly, the possible actions must be visible and identifiable

(*continued*)

Table 1. (*continued*)

Heuristics of the utility of smartphone		Nielsen's heuristics of utility	
Identifier	Description	Identifier	Description
HS7	Flexibility and shortcut work The smartphone should provide basic and advanced configuration options, let the user define and customize shortcuts to frequently used actions	HN7	Flexibility and efficiency Users should be able to fit the way of performing typical tasks to the level of their abilities to chosen functions
HS8	Aesthetics and minimalism Smartphone should be able to show needed information in the sensible time, also should avoid showing unnecessary information in the determined context of the use. The economical layout can increase the legibility, reduce the burdening of the eyesight and make shorter the time of searching for the information	HN8	Aesthetics and minimalism The design should not be unnecessarily loaded, and must be properly organized
HS9	Help to recognize, diagnose and correct errors Smartphone should show messages of the mistakes in language familiar to the user, indicating at the same time the type of the problem and theway of possible solution	HN9	Help to recognize, diagnose and correct errors Error messages should be expressed in natural language, precisely indicate the problem and propose a solution
HS10	Help and documentation The system should offer getting the documentation and help, focus on user's current task and showing concrete steps to do	HN10	Help and documentation The system should offer fast help for information required
HS11	Effectivenesses of the application and the productivity The device should be able to load and show requested information in the sensible time and minimize steps of the task to do. Animations andsteps should be shown smoothly	HS12	Physical interaction and ergonomics. The smartphone should ensure the physical buttons or similar elements of the user interface for major functions. The elements should be placed in a recognizable position. Dimensions, shape and user's interface elements should match the user's hands

1. making a telephone call from the contacts,
2. making a telephone call from the keyboard,
3. answering a phone call,
4. sending text messages,
5. reading text messages,
6. setting a new alarm,
7. adding a reminder to calendar,
8. changing ring settings, notifications and sounds

The evaluated tasks had been carried out under the same ambient conditions by experts divided into two groups of three people with a similar level of knowledge. For the evaluation, group number 1 used the Nielsen's heuristics HN1–HN10, and group number 2 used proposed new heuristics HS1–HS12.

As a result of the quantitative study, it has been identified a total of 51 utility problems, 21 utility problems identified by group 1 (HN), and 30 problems identified by group number 2 (HS). The number of problems of the utility and their degree of the intensity assigned to every heuristic is presented in Table 2.

Rates of the importance are showing increasing problems of the utility in the Likert scale 1–5. Suggested new method of estimation HS utility (average of the intensity 4.11) in comparing to heuristics of Nielsen (average of the intensity 3.32), showed the high accuracy and the utility in searching for problems of the utility of examined smartphone.

Table 2. Evaluation of problems of utility if smartphone in HN and HS heuristics. [own elaboration]

Group number 1 heuristics of Nielsen HN			Group number 2 heuristics of the utility of smartphone HS		
Identificator	Number of problems	Average of the rate of the importance	Identificator	Number of problems	Average of the rate of the importance
HN1	2	4,50	HS1	3	4,67
HN2	3	2,67	HS2	7	3,71
HN3	1	3,00	HS3	2	3,50
HN4	3	3,33	HS4	3	4,67
HN5	3	4,00	HS5	2	4,50
HN6	1	3,00	HS6	1	3,00
HN7	3	4,33	HS7	4	3,75
HN8	3	3,33	HS8	2	3,50
HN9	1	3,00	HS9	1	4,00
HN10	1	2,00	HS10	1	5,00
			HS11	2	4,50
			HS12	2	4,50
Total	21		Total	30	
The average intensity of utility problems 3,32			The average intensity of utility problems 4,11		

3 Suitability of Evaluation of Mobile for Smartphones

In terms of suitability for the elderly, there is no developed checklists containing heuristic evaluation usability of smartphones.

The starting point of evaluation of the utility of smartphones is the checklists and design guidelines developed for mobile phones. The environment of the evaluation of the utility of mobile phones known in literature is useful but isn't taking into account the aural and tactile aspect of user interface and more bigger screens in new smartphones.

There was developed new method of estimation of the utility for smartphones based on heuristics: HS1–HS12 and current checklists: [1, 9] and the environment of evaluation of the utility of mobile phones [10]. In the examination, the classification was based on the rates of the utility that uses the environment drawn up by [9] in order to compare smartphones at a high level of abstraction.

The author Jin et al. [1] they drew the list of the utility for examination of mobile phones which 3 were introduced in table in the hierarchical three-level structure of elements of the user interface Table 3.

Next in the examination procedure there were identified 21 principles of the utility, that were fulfilled to the user interface, which were grouped in five categories

A. cognitive support,
B. information support,
C. interaction support,
D. user support,
E. productivity support.

The author Ham et al. [10] they described three levels of the abstraction which in the hierarchical model are important for the evaluation of the utility: properties, criteria and indicators. In properties (for the first time) was appliedthe division of the user interface for: **LUI** (*Logical User Interface*), **GUI** (*Grafical User Interface*) and **PUI** (*Physical User Interface*). For the simplification of the evaluation there were suggested a way of classifying those results in the more general level. Five rates There were determined five

Table 3. Three-level structure of elements of the user interface (IU) [1]

Lp.	First level	Second level with examples	Third level with examples
1	Principles of operation IU	Menu, navigation, keyboard, icons	Main menu, groups of menu, tags
2	Screens IU	Menu screen Start screen Functions-based screen	Menu screen animation preview browser
3	Interactions IU	Types Sorts	Confirm, cancel and save changes, modification, delete
4	Component IU	Types Widgets Indicator	Menu list Bars, sliders, buttons Status indicators

rates: efficiency, effectiveness, aptitude for learning and in the arrangement - satisfying and adapting to the property and criteria. In this way it is possible to connect properties and criteria of the utility and the introduced model faciliate know better what kind of functions of the mobile phone influence on the utility.

A further continuation of these works was to develop by Heo et al. [10] environmental evaluation of the utility for smartphones *(framework)* containing four levels: (1) utility properties, (2) utility criterias, (3) utility rates and (4) mobile utility. They have been extracted the new indicators related to support: ergonomic, visual, cognitive interaction, efficiency and utility interaction. The user's interface elements of mobile phone were divided into groupes and assigned to: LUI, GUI and PUI:

– LUI related to the information about the content and structure, related to it performance (e.g. the menu structure and navigation),
– GUI interface with graphic elements and visual that shows the relevant information (e.g. icons and fonts),
– PUI physical interface that supports physical activities of users' performed tasks (e.g. physical keyboard and a microphone).

Environment of the evaluation of the usefulness of mobile phones introduced by Heo et al. [10] was focused on general evaluation of the device. Each level of this environment transferred the utility to the more abstract level, that uses multi-threaded taxonomy. Multi-threaded taxonomy allows to classification of the items of knowledge in many categories, in every level of abstraction. This allows the classification in a single category of unstructured data, such as the results of application [11]. There were divided the influence of the utility into three groups: (1) the perception of utility by users (effectiveness, efficiency), (2) the characteristics of a mobile phone (reliability, durability, performance and aesthetics), (3) the execution of the task (view of interaction: support and error prevention).

4 Evaluation Model of Utility of Smartphone for Elderly

The level of the utility of smartphones is affecting on increasing their utility through services of the mobile telecare for elderly people, but only under the condition of approval of new technologies. The is a deficit of the research tools that concerns this user group, in particular it concerns the criteria and indicators for the evaluation of the utility of smartphones with big touch screens. In order to develop simple indicators of evaluation of the utility of smartphones it was created an original model to evaluate their utility. For conducting empirical examinations, it was developed the following simple rates of the utility were drawn up:

1. Visual interaction support (**VIS**)
2. Cognitive interaction support (**CIS**)
3. Efficiency interaction support (**EIS**)
4. Usable functionality support (**UFS**)
5. Ergonomic support (**ES**)

A hierarchical model was developed, with the following levels of usability:

1. Characteristics of usability - observable and measurable characteristics of a smartphone divided into dependent and independent of the task by the user.
2. Criteria for usability - usability factors measured using a variety of checklists and applied to the indicators of usability.
3. Simple indicators of usability - conceptual constructs for pointing usefulnesses which are not directly measured.
4. General usability - two indicators of synthetic being the sum of simple usability indicators.

5 Closing Remarks

In the literature on the subject exist a statement where the experts deal with HCI can effectively detect problems of the utility. The main objective of the checklist is based on the discovery of reveal the design errors that reduce utility and recommendations for the improvement of errors are the final result [12]. An expert judging on the basis of a checklist may look for the inconsistency in the user interface. However, in the evaluation of the utility of smartphones for the elderly it is not the correct method. For that reason, in the planned second stage the evaluation wasn't applied with the help of experts from the first stage, since they don't have restrictions of limitations of functionality in the same extent, like elderly people.

In this stage of the examination, all elements from the checklist will be assessed by elderly people from two groups of the age which are: group 1 at the age of 65–74 and group 2 at the age above 75 years. The smartphones will be compared with checklists dependent and independent of performing a task and the evaluation of the utility will be executed based on the answers of elderly people to questions from above checklists.

In order to compare the overall usability of user interfaces for the elderly subjects of two operating systems smartphones, will be used synthetic indicator of performed tasks (**IPT**) and the synthetic indicator of the quality of use (**IQS**).

The increase of the utility smartphones for elderly people in the telecare is the effect of positive influence of value of the general usefulness is the result of value general utility listed with two above synthetic indicators. High usefulness of smartphones allows more effective performance of tasks, it reduce errors and shortens the period of the learning of elderly people.

The created method has many possibilities for the evaluation of overall utility of smartphones for all operating systems, but with the restriction concerning the size and features of the touch screen.

The developed methods can be a matching value for the user interfaces for designers and manufacturers of ergonomic smartphones which are useful for seniors.

References

1. Jin, Z.X., Plocher, T., Kiff, L.: Touch screen user interfaces for older adults: button size and spacing. In: Proceedings of Universal Access in Human Computer Interaction: Coping with Diversity (UA + HCI 2007), pp. 933–941, Beijing, China (2007)
2. Minkowski, A.: Rola samorządu terytorialnego w kształtowaniu aktywności osób starszych dzięki zastosowaniu technologii teleinformatycznych i e-usług. Biznes międzynarodowy w gospodarce globalnej, nr 32, pp. 147–157. Institute of International Business, University of Gdansk (2013)
3. Burdick, D.C.: Gerontechnology. In: Birren, J.E. (ed.) Encyclopedia of Gerontology: Age, Aging, and the Aged, pp. 625–627. Academic Press, Oxford (2007)
4. Sayago, S., Sloan, D., Blat, J.: Everyday use of computer-mediated communication tools and its evolution over time: an ethnographical study with older people. Interact. Comput. **23**(5), 543–554 (2011)
5. Nielsen, J.: Heuristic evaluation. In: Nielsen, J., Mack, R.L. (eds.) Usability Inspection Methods. Wiley, New York (1994)
6. Nielsen, J., Molich, R.: Heuristics evaluation of user interface. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 1990, pp. 249–256 (1990)
7. Nielsen, J.: Enhancing the explanatory power of usability heuristics. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Celebrating Interdependence, pp. 152–158. ACM (1994)
8. Kurniawan, S.: Older people and mobile phones: a multi-method investigation. Int. J. Hum Comput Stud. **66**(12), 889–901 (2008)
9. Mi, N., Cavuoto, L.A., Benson, K., Smith-Jackson, T., Nussbaum, M.A.: A heuristic checklist for an accessible smartphone interface design. Univ. Access Inf. Soc. **13**(4), 351–365 (2013). Springer, Berlin Heidelberg
10. Heo, J., Ham, D.H., Park, S., Song, C., Yoon, W.C.: A framework for evaluating the usability of mobile phones based on multi-level, hierarchical model of usability factors. Interact. Comput. **21**(4), 263–275 (2009)
11. Ji, Y.G., Park, J.H., Lee, C., Yun, M.H.: A usability checklist for the usability evaluation of mobile phone user interface. Int. J. Hum. Comput. Interact. **20**(3), 207–231 (2006)
12. Olszewski, J.: System pracy w warunkach globalnego społeczeństwa informacyjnego, pp. 68–73. Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu (2013)

Total Quality Management in the Improvement of Work Environment – Conditions of Ergonomics

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Abstract. Improvements in working conditions are a vital factor for an enterprise's growth. Commonly, such improvements are undertaken to increase a company's ability to respond to customer needs and expectations. However, it is vital to bear in mind that the potential for improvement is inextricably tied to the overall business environment. This is of particular importance for undertakings that operate systemically. The application of systemic principles, such as those prescribed by the TQM philosophy, helps complete improvements and identify areas in which improvements are necessary. In any improvement efforts, considerable significance should be ascribed to workers, the target area of measures and the people expected to benefit. To ensure proper conditions that make it possible to complete tasks, it is essential to refer to ergonomic requirements. For the measures taken to be effective, it is crucial to associate ergonomic requirements with the systemic principles enshrined in the TQM philosophy.

Keywords: Ergonomics · Total quality management · Work environment · Safety · Principles of improvement

1 Introduction

For a company to succeed in maintaining a dominant market position, it needs to continue to adapt to changing economic environments. For that to be possible, companies have to adopt such solutions aimed at preventing emerging issues as will enable them to adjust to operating conditions [1, 2]. Compliance with guidelines governing the change process is particularly crucial when modifying working conditions. Such compliance guarantees success in achieving the intended improvement outcomes. Nevertheless, even such modifications are bound to be felt as a disturbance of the company's routine operations forcing workers to meet new challenges.

Growth in any industry hinges heavily on the willingness to improve on prior achievements [3]. This concerns all areas of activity. The improvement process creates opportunities for an organization to work better and for the labor force to become more satisfied with their working conditions. The factors that define the level of satisfaction include:

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– Confidence in the company's choice of ways to operate,
– A recognition of the value of the company's efforts by the successive target groups,
– Worker expectations regarding the work environment.

A prerequisite for the overall enhancement of the process environment is to improve the conditions in which internal process performers operate. Improvements in such areas can be achieved by employing the principles of TQM, which allow organizations to secure a competitive advantage. As a consequence, workers, seen as the internal target group for such processes, become more satisfied [4–6].

2 The Nature of Improvements in Working Conditions

Ever greater importance for ensuring the proper growth of enterprises can be ascribed to human capital and operating conditions [1]. Therefore, a great deal of emphasis has been placed on the growing significance of worker health and safety protection. This, in turn, helps develop new behavior models based on new standards for organizational behavior and ethical norms.

Work process improvement can be defined as efforts aimed at ensuring that work proceeds in an optimal manner. To that end, it is vital to match the impacts of all threats occurring at particular workstations and all untoward factors with the improvement measures that are undertaken. Such measures determine the proper functioning of workers at the workplace and their ability to perform their jobs [7, 8]. The irregularities that occur at a workplace determine the choice of the systemic measures and solutions used to improve existing worker health and life protection systems. To accomplish such goals, it is necessary to adopt a consistent preventive policy that protects workers from occupational accidents and diseases. A key outcome of improvement measures is work comfort, which depends critically on conformity with ergonomic principles [9]. Any measures should account for the human factor thereby ensuring job satisfaction and motivating workers to continue along the path of improvement [4].

The measures taken to ensure that working conditions are improved properly are summarized in Table 1.

A precondition for the effectiveness of improvement measures is to ensure their proper implementation. To achieve this, an organization should account for the factors that determine the ability of workers to perform work effectively. To increase the organization's capacity to satisfy the related requirements, which includes improvements in working conditions, it is crucial to adopt solutions that will ensure that any modifications made have a lasting effect. Such solutions include the monitoring and assessment of an enterprise's strengths and weaknesses in the realm of working conditions to enable the company to choose and apply the most adequate improvement measures that reduce the adverse impacts of working conditions on the workers [10]. Such an approach will allow the organization to ensure that its work environment is permanently compliant with any applicable legislation and standards and meets worker expectations [11, 12].

Table 1. Actions taken to identify irregularities and take proper improvement measures

Stage of implementation	Description of state of implementation
Analysis of opportunities to adopt improvement measures	Requires that a proper account be taken of the organization's occupational safety policies, employee responsibilities, guidelines on the tolerance of threats and work division structures
Identification of irregularities and quantitative and qualitative assessment of their impact	Requires knowledge on the nature of any existing irregularities, the severity of their impact and the available options for preventing their effects
Planning and implementation of improvement measures	Requires that proper account be taken of the option to avoid threats, ensure a transfer of needs, mitigate the effects of irregularities and ensure conditions conducive to properly deploying improvement measures and defining emergency procedures
Monitoring and control of measure effectiveness	Requires continuous observations and supervision of any identified assessment factors, the identification of newly-emerged threats and assessments of the effectiveness of preventive measures

3 Total Quality Management in Work Environment Improvement

3.1 Nature of Improvements Pursued on the Basis of TQM Principles

Total Quality Management (TQM) rests on the assumption that an organization will seek to achieve lasting success. This desire on the part of the organization defines the conditions in which humans collaborate and the company's physical resources designed for the effective achievement of the adopted goals, such goals being customer satisfaction, the enterprise's profit and worker satisfaction.

At its essence, improvements rely on policies, the formulation of goals, the recognition of audit findings, an analysis of information and data, undertaking (corrective and preventive) improvement measures and recognizing the results of management reviews. By analyzing the available data, an organization will gain the ability to identify and assess the results of its improvement measures and its future improvement needs. The effectiveness of an organization's efforts may be used to assess the adopted improvement methodology.

The object of the improvement process is man [4, 13]. The goal of ensuring proper conditions for the operation of human workers should lie at the foundation of any improvement measures and be correlated with the nature of efforts undertaken in keeping with TQM guidelines. The strengthening of the position of an employee in an organization is seen as one of the key criteria of total management that complies with the principles of TQM. Such strengthening translates into the desired level of satisfaction achieved by the customer. It is therefore vital for workers to be empowered and more satisfied with their jobs and to make the organizational climate more worker-friendly [12]. By ensuring proper conditions for the functioning of employees (internal customers), organizations are in a better position to fulfill the expectations of external clients.

TQM principles can be described as factors that define the direction for improvements [3]. As suggested in the TQM philosophy, improvements should include comprehensive as well as regular enhancements in work quality and the approach to management while reducing environmental impact. Growth can best be secured by committing to a set of measures that include planning, decision-making, organization, leadership and control designed to ensure that the adopted goals are pursued efficiently and effectively [5].

3.2 TQM in Working Conditions Improvements

The TQM strategy requires workers to engage in efforts to ensure continuous improvements in every area of their company's activities [14]. The main precondition for accomplishing such work culture is to support worker efforts to achieve success. Such efforts may involve modifications of the work environment with a view to improving the possibilities of employees operating effectively.

A company's success in establishing a management system that will underpin TQM depends on compliance with four basic rules concerning quality. The rules state that [11]:

- High quality is a company's prime objective,
- Quality needs to be pursued by every employee,
- Quality is multifaceted and comprises the organization's people, processes and systems, including the work environment,
- Quality is better achieved by preventing problems rather than detecting defects.

One prerequisite for ensuring the capacity to improve is to relate improvement measures to any essential aspects of an organization's growth. These may include measures aimed at [14, 15]:

- Defining operational plans and specific qualitative tasks,
- Assigning tasks to specific executive units,
- Modifying the organizational structure to reflect the needs of the new strategy,
- Building up a proper organizational culture in the company,
- Maintaining a proper level of leadership,
- Developing a system of incentives and controls for the actions taken that will be suitable for the pursuit of the adopted strategy.

In keeping with TQM guidelines, the measures, defined in the above manner, may be seen as resting on eight management principles that cover key aspects of an organization's functioning. Such principles are summarized in Table 2.

In order to ensure that the improvements relying on TQM principles are efficient, it is vital to [16]:

Table 2. An approach to implementing management principles consistent with the TQM philosophy.

Management principle	Guidelines for the principle's implementation
1. Customer orientation	– an organization's operation and growth depends on customer demand, – an organization must satisfy the expectations of all of its customers, – to secure the desired benefits, an organization needs to create a positive image, – to secure the desired benefits, an organization needs to ensure that its strategic objectives reflect customer expectations
2. Leadership	– to establish leadership, an organization needs to define its goals and objectives, – leadership relies on the outcomes of shaping an organization's internal operating environment that will support its pursuit of its adopted goals
3. Worker involvement	– optimal conditions must be created to attain the expected commitment level – this, in turn, will enable the organization to use its workers' abilities for its maximum benefit
4. Process approach	– requires designing optimal ways to carry out measures necessary for the achievement of the adopted goals, – requires the identification, integration and systematic improvement of processes with a view to increasing their effectiveness, – requires measures that reflect the rule that processes can only be conducted if proper resources have been allocated, – requires defining the scope of information and knowledge that needs to be gathered as a precondition for the proper operation of processes and the achievement of the adopted goals
5. Systemic approach to management	– the main message in the systemic approach is to seek to establish optimal links between any identified processes and their management as a process – the result is a greater efficiency and effectiveness in the implementation of measures
6. Continuous improvement	– improvement is an overarching purpose behind the efforts of any organization, – improvement is defined as the pursuit of repeated actions designed to enhance the ability to satisfy requirements, – continuous improvement must be sought at every workstation, extend to every identified process and become a permanent system outcome
7. Fact-based decision-making	– decisions are made on the basis of a logical analysis of the available data and information
8. Mutual beneficial links within organization	– the adopted optimization of relations with all parties and the development of partner relationships will increase an organization's ability to sustain lasting cooperation

- Identify the processes taking place in an organization,
- Define sequences and mutual impacts,
- Define evaluation methods and criteria as well as resources that ensure the effectiveness of processes and their supervision,
- Ensure continuous monitoring, analysis and improvement of processes.

One task of utmost importance is to designate process owners responsible for their implementation and for improvement results [17]. The improvements to be undertaken may concern new technologies and materials as well as better work organization.

3.3 Areas of Benefits Derived from Systemic Improvement

Improvement can be defined as the part of the management process that is focused on increasing the ability to satisfy requirements. Improvement, therefore, may be equated with projects designed to achieve additional benefits for both the organization, its workers and its customers [11]. To ensure that a company that sets out on employing TQM principles develops sustainably, occupational health and safety solutions need to be integrated into the overall approach to management. To define comprehensive conditions for shaping occupational health and safety that are consistent with TQM requirements, proper rules should be followed to ensure the effectiveness of the measures taken. Improvements across multiple fields of a company's operations must be seen as necessary [3]. The improvement methods and the scope of improvement actions in an organization determine its competitive position. Pursued in such a fashion, improvements require that:

- workers be encouraged to step up efforts to shape working conditions,
- workers be involved in implementing improvement measures and assume ownership of the methods of task performance,
- workers be empowered to make unsupervised decisions.

In an effort to promote the growth of an organization, the above measures may be based on management guidelines covering various areas of an organization's business. Of particular importance in this context is the shaping of a safety culture and undertaking actions consistent with corporate social responsibility [18, 19].

Organization culture describes the values shared by an organization that affect the way individual workers function within its structures. Culture in this sense is a collection of social norms and value systems that stimulate interpersonal relations among members of the organization that are critical for achieving specific goals. Such culture is made up of standards, models, rules and the principles of conduct adopted in a given environment [20]. A part of the overall culture is the culture of safety which defines the approaches and behaviors of an organization's members allowing them to make decisions to improve safety and promote health within the organization [22].

Corporate social responsibility is defined as the degree to which a company's operations are ethical. Such responsibility comprises [18, 19, 21]:

- the implementation and improvement of an organization's growth strategies aimed at satisfying stakeholder needs and expectations,
- building positive relations with the environment,

- ensuring that actions are consistent with legal requirements and other commitments made by the organization,
- adopting innovations that allow the company to be more effective in its actions,
- improving resources,
- ensuring process safety.

A central focus of efforts to modify working conditions through specific measures is man – no organization can ever lose track of this principle. An organization willing to self-improve needs to learn about human needs and be able to describe their requirements and expectations. In order for an organization's measures to produce the desired results, they must be consistent with the enterprise's action strategy. Elements of that strategy must be inextricably linked to key areas of a company's operations. Only then will the organization be able to operate efficiently and effectively.

In the search for a balance in fulfilling the expectations of all stakeholders, an organization needs to display integrity, respect dignity and abide by the ethical rules in the achievement of its intended outcomes. It needs to recognize that a part of its effort is to achieve compliance with the ergonomic criteria applicable to its work environment [18].

Ergonomic criteria play an important role in defining requirements that describe qualitative aspects of the work environment. Traditionally, such aspects are identified in the form of ergonomic norms or norms that contain ergonomic requirements and that can potentially be associated with ergonomic criteria. Ergonomic criteria extend mainly to the human factor and to its role in pursuing business objectives, often becoming critical for the successful completion of measures [9].

4 Ergonomic Requirements Applicable to Improvement Consistent with TQM

Ergonomic requirements are typically associated with the creation of friendly working conditions in keeping with applicable laws. A less common consideration are the financial benefits to be derived from creating an environment that is conducive to the effective functioning of an organization [23]. To strengthen the role of ergonomics and ensure possibilities for the achievement of the desired benefits, an enterprise should identify the positive effects of applying ergonomic requirements to improve its operation. These can be approached by focusing on [24]:

- The current status in which ergonomics forms a part of the planning process,
- The desired status in which ergonomics is an integral part of the strategy that an organization formulates and pursues.

An essential part of such measures is to account for the need to apply ergonomic requirements seen as prerequisites for the improvement of occupational health and safety [25]. The assumption that needs to be made is that ergonomics is a vital part of the process of shaping the work environment. Its goals are achieved by adopting a pro-humanistic approach to shaping an organization's relations with the environment in which it operates as well as its internal clients, i.e. the company's workers. All such actions are undertaken to find the best ways to optimize the loads that workers encounter in their work.

To ensure that optimization efforts help to efficiently define worker loads, it is crucial to define the scope of requirements that should be accounted for in shaping working conditions. An integral part of such conditions are ergonomic requirements. The links between ergonomic requirements and TQM principles are presented in Table 3.

Table 3. Ergonomic requirements adopted with respect to management principles, consistently with the TQM philosophy.

	Management principle	Principle implementation
1	Customer orientation	– in its pursuit of its tasks, an organization follows all ergonomic requirements that affect worker efficiency, – much significance is ascribed to the conditions in which the organization's internal clients operate as well as their needs and expectations
2	Leadership	– ergonomic guidelines are seen as part of an organization's mission, vision and operating strategy, – the organizational culture that is subject to modifications includes the culture of safety which accounts for ergonomic requirements associated with work comfort, – in its approach to activities, the organization accounts for social aspects and how they are influenced by ergonomic requirements
3	Worker involvement	– the organization creates conditions in which employee involvement can be utilized in the improvement effort, – in the adopted improvement measures, proper account is taken of worker comments indicating the need for solutions that increase work comfort
4	Process approach	– the allocated resources include knowledge on how to perform tasks with proper account taken of factors affecting the ability to achieve the desired outcomes, including benefits in the realm of working conditions, – ergonomic requirements are seen as a prerequisite for the effective completion of processes that allow the company to accomplish its specific goals
5	Systemic approach to management	– compliance with ergonomic requirements is seen as a precondition for process effectiveness and efficiency
6	Continuous improvement	– an increased capacity to satisfy requirements is achieved by adopting ergonomic principles that help the organization operate more effectively, – improvements in operating effectiveness are achieved in all processes and at all workstations and are seen as critical for the organization's operation
7	Fact-based decision-making	– ergonomic requirements are seen as some of the data and information necessary for decision-making
8	Mutual beneficial links within the organization	– the adopted requirements help improve relationships with all parties participating in business activities

5 Summary

In their actions, enterprises increasingly recognize the importance of new areas for improvement pursued in accordance with TQM guidelines. Such areas include:

– Developing an occupational safety culture,
– Shaping social responsibility with proper account taken of various aspects of work processes.

Such efforts produce a number of benefits which include:

– Greater positive interest on the part of existing and prospective stakeholders,
– Greater customer loyalty,
– Favorable relations with the public,
– A positive image among the workers achieved by investing in their development and implementing standards that underpin policies, thus contributing to the enhancement of organizational culture.

An aspect of an organization's growth that certainly deserves to be seen as critical is the commitment of workers to contribute to the improvement process and an effort to embrace ergonomic guidelines in that process. Ergonomics helps improve the potential for completing tasks. The direct result is greater work efficiency [26].

The TQM structure that an organization employs must be placed in a safe environment. In this context, the main role of ergonomics is to ensure comfort and reliable equipment and eliminate general fatigue as well as fatigue resulting from exposure to specific working conditions.

Enterprises that abide by the principles of TQM in their operations must be aware of the need for all workers to strongly commit to the improvement process. This helps achieve the expected benefits in many fields. For instance, compliance with the ergonomic requirements relating to the work environment helps improve work efficiency, reduce the biological cost of work and cut the number and cost of errors made during work [24]. As a consequence, the concerned enterprise improves its competitive position.

References

1. Malara, Z.: Determinanty rozwoju współczesnych organizacji gospodarczych. In: Lachiewicz, S. (ed.) Zarządzanie rozwojem organizacji, t. 1, pp. 56–66. Wydawnictwo Politechniki Łódzkiej, Łódź (2007)
2. Carré, F.J.: Working Conditions. In: Wright J.D. (ed.) International Encyclopedia of the Social & Behavioral Sciences, 2nd edn., pp. 698–702. Elsevier (2015)
3. Skrzypek, E.: Jakość a doskonalenie organizacji. In: Sikora, T. (ed.) Zarządzanie jakością. Doskonalenie organizacji, vol. 1, pp. 214–225. Cracow University of Economics, Kraków (2010)
4. Górny, A.: Man as internal customer for working environment improvements. Procedia Manufact. **3**, 4700–4707 (2015)
5. Kiran, D.R.: Total Quality Management, Key Concepts and Case Studies. Butterworth Heinemann, Elsevier, Amsterdam (2017)

6. Tisca, I., A, Cornu, G., Diaconu, N., Dumitrescu, C.D.: Diagnosis, risk and efficiency in the implementation of TQM in small and medium enterprises. Procedia Econ. Finan. **26**, 215–218 (2015)
7. Górska, E., Tytyk, E.: Ergonomia w projektowaniu stanowisk roboczych. Podstawy teoretyczne. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa (1998)
8. Matczyński, F.: Organizacja pracy na stanowiskach roboczych. Wydawnictwo Naukowo-Techniczne, Warszawa (1978)
9. Górny, A.: Ergonomics in the formation of work condition quality. Work: J. Prev. Assess. Rehabil. **1**(supp. 1), 1708–1711 (2012)
10. Górny, A.: Work environment in quality assurance. In: Arezes, P., et al. (eds.) Occupational Safety and Hygiene, SHO 2016, pp. 105–107. Portuguese Society of Occupational Safety and Hygiene (SPOSHO), Guimarães (2016)
11. Hamrol, A.: Wybrane myśli o dążeniu do doskonałości w zarządzaniu jakością. In: Sikora, T. (ed.) Zarządzanie jakością. Doskonalenie organizacji, vol. 1, pp. 86–101. Cracow University of Economics, Kraków (2010)
12. Ugboro, I.O., Obeng, K.: Top management leadership, employee empowerment, job satisfaction, and customer satisfaction in TQM organizations: an empirical study. J. Qual. Manage. **5**(2), 247–272 (2000)
13. Gołaś, H., Mazur, A.: Macroergonoimic aspects of a quality management system. Found. Control Manage. Sci. **11**, 161–170 (2008)
14. Penc-Pietrzak, I.: Analiza strategiczna w zarzadzaniu firmą. Koncepcje i stosowanie. C.H. Beck, Warszawa (2003)
15. Rokita, J.: Zarządzanie strategiczne. Tworzenie i utrzymywanie przewagi konkurencyjnej. PWN, Warszawa (2003)
16. EN ISO 9001:2015 (PN-EN ISO 9001:2015-10), Quality managements systems. Requirements (ISO 9001:2015). CEN - CENELEC Management Centre, Brussels (2015)
17. Fleming, D., Lynch, P., Kelliher, F.: The process of evaluating business to business relationships facing dissolution: an SME owner manager perspective. Ind. Mark. Manage. **58**, 83–93 (2016)
18. Górny, A.: Ergonomics aspects of CSR in system shaping the quality of work environment. In: Vink, P. (ed.) Advances in social and organizational factors, pp. 541–550. CRC Press, Boca Raton (2012)
19. Bonsón, E., Bednárová, M.: CSR reporting practices of Eurozone companies. Revista de Contabilidad **18**(2), 399–413 (2015)
20. Czerska, M.: System narzędzi kształtowania kultury organizacji. In: Lachiewicz, S. (ed.) Zarządzanie rozwojem organizacji, vol. 1, pp. 39–47. Wydawnictwo Politechniki Łódzkiej, Łódź (2007)
21. Roberts, P.W., Dowling, G.R.: Corporate reputation and sustained superior financial performance. Strateg. Manage. J. **23**(12), 1077–1093 (2000)
22. Cooper, M.D.: Towards a model of safety culture. Saf. Sci. **36**(2), 111–136 (2000)
23. Dul, J., Neuman, W.P.: Ergonomics contribution to company strategies. Appl. Ergon. **40**(4), 745–752 (2009)
24. Górny, A.: Ergonomic requirements in system management of industrial safety. Found. Control Manage. Sci. **11**, 127–138 (2008)
25. Górny, A., Sadłowska-Wrzesińska, J.: Ergonomics aspects in occupational risk management. In: Arezes, P., et al. (eds.) Occupational Safety and Hygiene, SHO 2016, pp. 102–104. Portuguese Society of Occupational Safety and Hygiene (SPOSHO), Guimarães (2016)
26. Eklund, J.: Development work for quality and ergonomics. Appl. Ergon. **31**(6), 641–648 (2000)

Improvement of Interactive Products Based on an Algorithm Minimizing Information Gap

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Abstract. This paper feature results of scientific research that is associated with the improvement of interaction conditions of interactive products. Efficiency of use of these products remains in close correlation with efficient performance of decision making processes. Available information resources assist the user in the effective use of electronic devices only when, at the same time, mechanisms of adaptation of information to the real needs and learning capabilities of the individual user in the information environment are being designed. This multi-dimensional space in which cognitive processes are carried out, in regard to processing and transferring information, is nowadays characterized by excessive amounts of information, also called information noise. However, in the use of interactive products, the common phenomenon of the so-called information gap, which is the difference between relevant information and the collection of information became available in the system. The result of designing interactive products targeted at eliminating this discrepancy is that the user achieve goals with satisfaction, in less time and without frustration and anxiety, which would otherwise occur as a result of emotional and cognitive dissonance.

Keywords: Decision making processes · Cognitive processes

1 Introduction

The most important task for the IT product designer is to develop mechanisms to provide set of information, which will be used by the user during interaction, assessing the current situation and making appropriate decisions [1, 2]. The designer solves problems supporting user's limitations, which are described by [3] in his work on human-computer interaction. Moreover he or she designs interface, which reflect in possibly most vivid way the information structure of operating environment. Thanks to the plasticity of mapping the elements of sought reality, the user is able to project the images of operational environment, restore from memory the missing pieces of information and make sound decisions. Basic limitation of humans, related to the existence of information gap include:

– "visual limitations: ability to flawlessly read information from the screen, the screen layout should enable the user to clearly separate work areas and easily access objects in these areas;

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– limitations associated with human's memory capacity and ability to process data: the manner of information coding should allow for flawless decoding;
– limitations of manipulation efficiency," [3].

The scope of knowledge about the information-processing by humans, implemented in the interactive product design is directly proportional to the effectiveness of tasks and user satisfaction and inversely proportional to information gap. A foundation in these proceedings is to maintain the generally accepted guidelines for interaction design, published by the authors dealing with human-computer interaction [4, 5]:

– supporting work tasks;
– taking into account the limitations of humans;
– assuring the enjoyment of use;
– using experience;
– understanding the characteristic of the problem situation.

Fundamental goal of designing is improving the interface through all sorts of measures:

– ensuring normal flow of information processes, which reduce the load on the visual system in regard to seeing objects,
– ensuring correct logic of information appearing,
– ensuring human's ability to keep all necessary information in the so called operating memory,
– ensuring the development of specific action strategies, e.g. possibility to acquire additional information.
– introducing harmony of use (visual and auditory stimuli contained in color schemes and sound settings)

The fundamental criteria of design in the evaluation of the interface reducing the information gap is the set of quality and ergonomic requirements [6–9]. They include, among others, the following requirements: currentness, completeness, detailed character, reliability, availability, comparability, appropriate reaction time and proper fit between the system and the real world, consistency and standards, preventing errors, recognition instead of reminders, flexibility and the ability to use shortcuts at work, aesthetic and creative design [10–12].

A large number of these requirements force the designers of interactive products to find in the course of numerous experiments, the significance of some of the requirements against the others [7, 8]. In the course of these experiments, based on user's subjective assessment, relationships between measures in the information environment of decision-making processes are defined. Results of research regarding the improvement of conditions of perceiving information, understanding information and regarding the assessment of information usefulness during interaction are presented in Table 1.

Table 1. Summary results of research on efficiency of ergonomic design of operator work method interface [5]

Information means	Characteristic of work processes	Assessment criteria of method of using interactive product		
		Perception [relative response time]	Understanding [adequacy of choice - in two categories, in the unit of time]	Assigning appropriate category of importance [aptness on a scale 1 to 5]
Effects of shifting attention by breaking the rules	A. Sewage treatment technology operator	Improved by 30%	Correct	Correct
	B. Executive team operator	Improved by 5%	Correct	Overstated
	C. Executive devices operator	Improved by 2%	Correct	Correct
	D. Safety conditions monitoring system operator	Improved by 21%	Correct	Correct
Eliminating words, which are not emotionally neutral	A. ditto	Improved by 5%	Correct	Overstated
	B. ditto	Improved by 7%	Incorrect	Overstated
	C. ditto	Improved by 3%	Correct	Correct
	D. ditto	Improved by 12%	Correct	Overstated
Reducing the number of sources of information	A. ditto	Improved by 24%	Correct	Correct
	B. ditto	Improved by 2%	Correct	Correct
	C. ditto	Improved by 2%	Incorrect	Correct
	D. ditto	Improved by 3%	Correct	Correct

2 Methodological Bases to Minimize the Information Gap

Properly designed interactive product requires associations and synthesis of data research methods of various origins with a specific situation of human-object interaction. I real situations, the value sought by the designer depends on the state of “n” parameters, which constitute a multi-dimensional sphere of data and moreover a synergy between these parameters is the core of the designed solution. Choice of possible solutions during minimization of information gap requires reduction of a number of variable factors "n" to the most important for a given human-interactive product system, with regard to technical and psychological aspects.

Since the tasks of a user are focused on constant processing of information, therefore general requirements regarding the functioning of IT devices users are treated as an autonomic system, in which searching, receiving, processing and storing of information from the environment along with decision making processes occurs.

In the set of preliminary criteria of product improvement there will be those, which are identified with the following three issues:

1. perceiving information by the user;
2. understanding the content of information;
3. assessment of the level of perceived information;
4. selection of the variant of sought information, when there is abundance of it.

Therefore the criteria of the evaluation of effectiveness of decision making actions are the following:

- minimal time to perceive and process information,
- comprehensibility (clarity) of the content of information,
- correctness of the assessment of the importance of the perceived information,
- ability to use the information in decision-making.

In order to justify the implementation of appropriate information means, it is required to describe the process of usage in the observable categories of cognitive processes (Fig. 1).

Three phases were distinguished during experiments, were suggested:

1. Phase of acquiring information with concurrent analysis of information (searching for alternative variants);
2. Phase of decision making;
3. Phase of executive action of decision making processes.

Acquiring information is based on direct observation of the interface. In this phase the main emphasis is on the perception of various visual, auditory and tactile information and appropriate reaction to them. This causes an absorption of certain intellectual resources, particularly memory and attention. The more complex is the device the more information and knowledge is required to properly handle it and correctly perform the task. Analysis of information includes thought processes leading to establishing a hierarchy of information variants with regard to the expected usefulness in the decision-making process and its practical use (carried out with a use of decision rules). Decision making refers to situations in which the user has to take action with regard to more than one piece of information [13]. In case of repetitive decisions, which are typically taken quickly, even automatically, mental effort involved is small. If however the decision is more complex, it requires the use of large amounts of information, often incomplete and associated with a lot of responsibility.

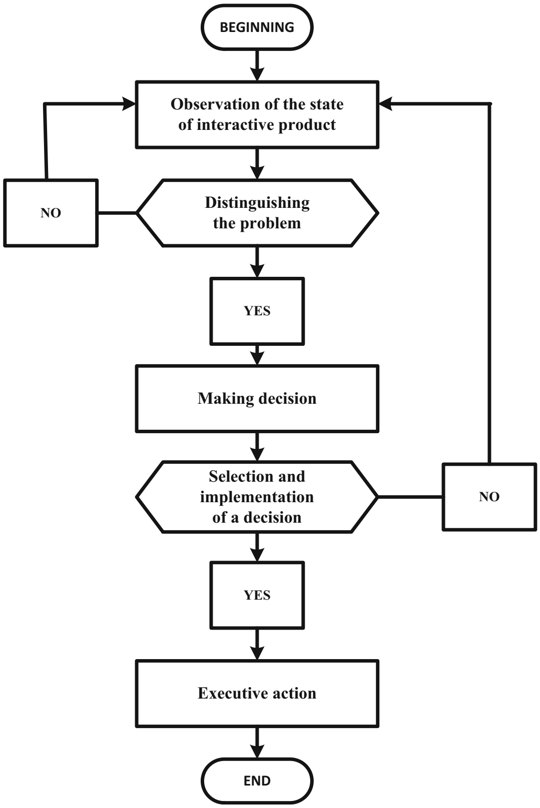

Fig. 1. Conceptual model of a tasks of an interactive product user. Own elaboration

Executive actions primarily depend on the complexity of tasks, the degree of practice, typicality or abnormality of movements, particularly from the consequences of their implementation in a complex decision-making process as shown in Fig. 2.

The occurrence of the information gap is most generally justified by selection process, which determines the information reaching the human, and which cannot be processed by him or her.

Knowing that brain can flexibly change strategies of dealing with information in environment and thanks to appropriate factors in creating a system of ideas, which are achieved through adequate information measures in the designed systems. A strategy of the so called active operator is an example of a complex solution, which is focused on the effect of supporting orientation attention. Thanks to this strategy, rigid boundaries of brain capacity don't exist and information gap can be significantly reduced in decision making processes and executive tasks can be improved.

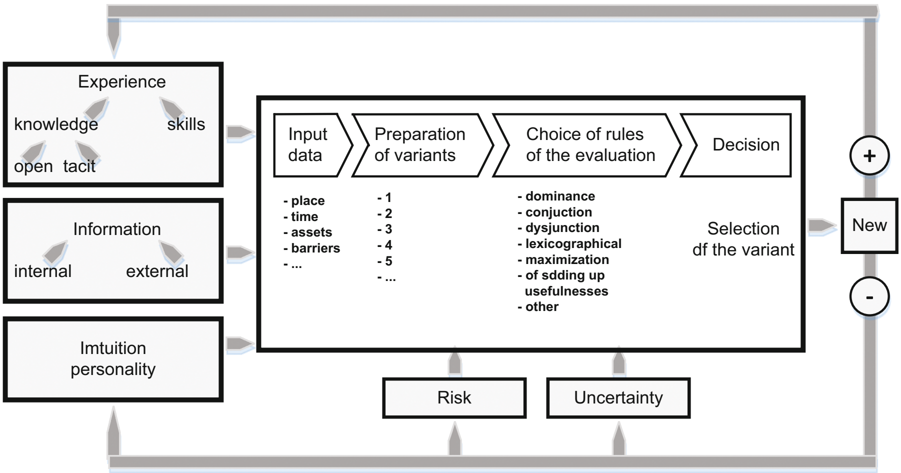

Fig. 2. Structure of elements constituting the relationships in decision making cycle [14].

3 Algorithm of Minimization of Information Gap

Initially starting from the standard approach to the design of interactive products of high usability according to ISO 13407 norm, in many design projects the ability to improve the efficiency of research by restricting their scope to specific cognitive processes has been observed. In this area the activities of users of interactive products associated with decision-making were accepted as representative, in relation to which the validation of interface was prepared and carried out with positive results. A method of improvement of interaction requires 9 stages as shown in Fig. 3.

Stage 1: Preliminary analysis of historical data. Relationships in the user's environment in case of performance failure are recognized. Availability of this type of data enables identifying distractors and initially defining the sources of information gap. It is when the diagram of information flow is designed for the system human - interactive device – information environment.
Stage 2: It is required to document the cases of using a taxonomy characterizing the action for cognitive processes. A description of user's tasks is created and the knowledge about improper behavior of the user is supplemented.
Stage 3: Information means supporting user's decision making tasks are designed. The objective for the design is to include an optional solution for each individual task.
Stage 4: Planning training and exercises, during which the use of interactive product is forced in the situation of stress and lack of time. The assessment of effectiveness of feedback is required.
Stage 5: Documenting the effectiveness evaluation of user's tasks in difficult situations. A simulation of the information means used in executive actions of decision-making tasks under stress and lack of time.
Stage 6: Recording reaction times.
Stage 7: Identification of distractors.

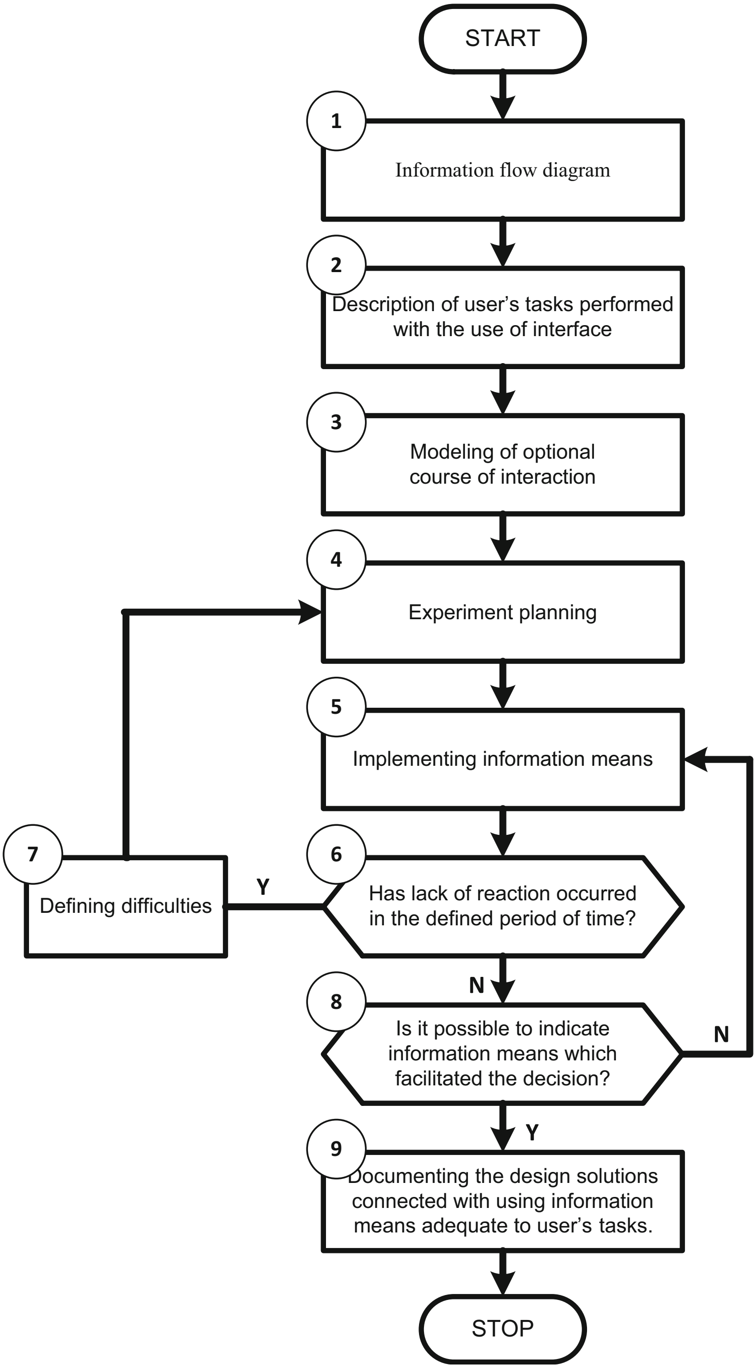

Fig. 3. Algorithm of minimization of information gap. Own elaboration

Stage 8: Selection of information means facilitating the decision making during interaction.
Stage 9: Describing the design solutions supporting user during interaction. The design is being enriched with innovative solution. The implementation of the project module is being implemented, which allows the user to actively participate in the creation of interactive products in the re-validation stage. The effectiveness of user's tasks in situation modeled personally by the user is compared.

Experience in regard to information means optimizing the work of interactive products' users during decision making activities are related to the following four areas of research:

1. Reducing the load on visual system with regard to seeing objects;
2. Guaranteeing maximally accurate reception of information provided by the indicating device;
3. Facilitating the including of information appearing "at the input" of the subjective sphere (a human creating a subjective model of activities);
4. Ensuring human's ability to keep all necessary information in the so called operating memory.

4 Conclusion

Ergonomic approach in minimization algorithm of information gaps in interactive products fulfills the postulate of individual adjustment of technique to user's abilities. Using adequate information means generates the transmission of information in such portions that none of them will exceed the capacity of its reception, and all of them together guarantee necessary fullness to reflect the reality.

Designing interface with knowledge of human's information processing processes, of cognitive processes which characterize executive actions of decision making processes influences directly the scope of information gap.

The suggested algorithm of minimization of information gaps provides knowledge about problem situation and situational context I which the processing of information of interactive product user occurs. Making use of the phenomenon of time deficit during critical test at the stage of design validation additionally provides data about conditions of fallibility of user's activity efficiency and test the device for compliance with human's characteristic. If the human-interface system is to function effectively, it is necessary that information addressed to man is transferred to him or her in the most convenient form to be noticed, remembered and understood. Analyzing the model of information processing we can distinguish components activating the user. Therefore, the base of interactive product design is the conceptual model of user's tasks along with specific activities of the cognitive system.

Interface of every interactive product integrates all elements of the system, between which the information exchange occurs. It constitutes a hub which filters the exponentially growing amount of data which are fed to the system, which provides resources for the user. The smaller the scope of information gap the better protected is the human in the context of information noise and the more favorable and the "mechanisms responsible for planning, decision making, discovering errors, reaction in new situations and refraining from habitual reactions," [8].

References

1. Jasiulewicz-Kaczmarek, M., Saniuk, A., Nowicki, T.: The Maintenance Management in the Macro-Ergonomics Context. In: Goossens, R.H.M. (ed.) Advances in Social & Occupational Ergonomics. Advances in Intelligent Systems and Computing. 7th International Conference on Applied Human Factors and Ergonomics (AHFE)/International Conference on Social and Occupational Ergonomics, Walt Disney World, Bay Lake, FL, 27–31 July 2016, vol. 487, pp. 35–46 (2017)
2. Szafranski, M.: Acceleration of educating as an external factor supporting preventive and improving actions in businesses. In: Ahram, T. Karwowski, W. Schmorrow, D. (eds.) Procedia Manufacturing; 6th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences, AHFE 2015, vol. 3, pp. 4948–495 (2015)
3. Sikorski, M.: Interakcjaczłowiek-komputer (Interaction Human-Computer) Wydawnictwo PJWSTK, pp. 53–56 (2010)
4. Jaśkowski, P.: Neuronaukapoznania. Jakmózgtworzyumysł (Neuroscience Knowledge. How the Brain Creates the Mind). VIZJA Press & IT, Warszawa, pp. 220–221 (2009)
5. Sharp, H., Rogers, Y., Preece, J.: Interaction Design. Beyond Human-Computer Interaction. Wiley, New York (2005)
6. Suchman, L.: Plans and Situated Actions. Cambridge University Press, New York (1990)
7. Sławińska, M., Jurga, A.: Qualitative and ergonomic criteria of designing information systems supporting logistic processes. Res. Logistics Prod. **2**(1), 81–90 (2012)
8. Sławińska, M.: Operator interaction with control devices – ergonomic design in industrial automatics, Ergonomia. Int. J. Ergon. Hum. Factors **33**(1–4), 147–163 (2011). Committee on Ergonomics of the Polish Academy of Sciences, Kraków
9. Kujawińska, A., Vogt, K., Wachowiak, F.: Ergonomics as Significant Factor of Sustainable Production. In: Golińska, P., Kawa, A. (eds.) Technology Management for Sustainable Production and Logistics. EcoProduction, pp. 193–203 (2015). doi:10.1007/978-3-642-33935-6_10
10. Hamrol, A., Kowalik, D., Kujawinska, A.: Impact of selected work condition factors on quality of manual assembly process. Hum. Factors Ergon. Manufact. Serv. Ind. **21**(2), 156–163 (2011). doi:10.1002/hfm.20233
11. Kujawińska, A., Vogt, K., Hamrol, A.: The role of human motivation in quality inspection of production processes. In: HAAMAHA. Advances in Intelligent Systems and Computing, vol. 490, pp. 569–579 (2016)
12. Kujawińska, A., Vogt, K.: Human factors in visual control. Manage. Prod. Eng. Rev. **6**(2), 25–31 (2015)
13. Waszkowski, R., Nowicki, T., Saniuk, A.: Human-computer interaction in sanitary inspection simulation exercises. In: Soares, M., Falcão, C., Ahram, T.Z. (eds.) Advances in Ergonomics Modeling, Usability & Special Populations: Proceedings of the AHFE 2016 International Conference on Ergonomics Modeling, Usability & Special Populations, 27–31 July 2016, Walt Disney World®, Florida, USA. Cham, pp. 245–254. Springer International Publishing (2016). http://dx.doi.org/10.1007/978-3-319-41685-4_22
14. Więcek-Janka, E.: Games and decisions. Publishing House of Poznan University of Technology (2010)

Diagram Process as a Tool to Improve Communication Process Inside a Company – Case Study

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Abstract. A subject of the paper is a process diagram of data input to IT system, as a tool to improve communication process inside company. Observational research as well as reports of errors and missing data created for administrator of IT production management system, were carried out under real conditions of company of producing machine parts. These research provided with the knowledge about quality of communication between various organizational units (departments) within the company and between the IT system users as well. Presented diagram, with clearly defined steps, specifies method of filling up the IT system with technological, planning, manufacturing, purchasing, subcontracting and controlling data, improving this way internal communication process.

Keywords: Communication process · Communicate · Process diagram · Block diagram

1 Introduction

Communication as a process of transferring or exchanging information between people, is one of the oldest social processes which accompanies a human from the moment he began to live in a groups, community and organized structures. Contemporary societies exist thanks to creating, processing and transmitting information. It means that communication processes are foundation of society which could not function without it. These processes are carried out on several levels, dependently on social context. The lowest level creates interpersonal communication units, then we can distinguish intragroup and between group communication. Next, it is higher institutional communication or even higher public communication, including political, and finally the highest – mass communication [1].

2 Communication as a Process

Many definitions of communication concept were founded in science of communication. Their authors point out different aspects, features and elements of the phenomenon assigning them to different meaning. Communication was thus defined as a mechanism

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by which human relationships exist and develop [2], as a tool that allows society to exist [3], as an act through which group norms are expressed, social control is performed, roles are assigned and efforts are coordinated [4], or as a transactional process of creating meaning by its users at interpersonal and public level [5]. On the basis on that analysis, it can be accepted an universal definition that communication is a process of communicate, sending information between individuals, groups or institutions. Its aim is to exchange thoughts, sharing knowledge, information and ideas. This process takes place at different levels of organization, using a variety of measures and causes specific effects.

3 Communication System

The concept of communication system can be defined in two ways [1]:

- in institutional terms – shows connections between the system components (institutions, groups), their location, type, kind,
- in functional terms – shows the system as a process, highlights actions and interactions.

Communication system will exist when interpersonal communication of individuals and small groups is replaced by a complex, multifaceted and multi-layered communication process, as well as there will be a message sender and receiver forming a structured group of people.
The type of communication system is determined by the following factors [1]:

- participants of the system, composition, structure and features,
- control of sending messages, methods and ways of their distribution,
- information sources and methods of delivering them to the system, to senders and receivers,
- nature of contacts between members of the system,
- rules, norms, behaviour patterns of the system members.

These factors made it possible to distinguish various communication systems (organizational, political, public, mass), which were created together with civilization progress. All of these systems have a social nature, because their participants are members of society.

The concept of social communication system can be defined as a totality of communication relationships, involving creation, accumulation and receiving information between participants of the system.

4 Organizational Communication System

A proper information flow is essential for functioning company. This is one of the most important processes related to management system [6].

The organizational communication system corresponds to the communication processes at group level and between groups. This makes, the narrowest and the smallest range. The participants of this system are individuals – people who belong to organization characterized by internal, hierarchical structure with clearly defined roles of its members. Relationships between participants of this system are formal and organizational. All participants have got assigned duties and responsibilities, which perform them to achieve goals [1].

The communication inside closed organization structure is carried out on the two levels: interpersonal and group. Interpersonal communication is associated with information transfer from management to subordinates. Group communication takes place inside a team performing a common task.

Studies concerning communication processes in organizational communication system contributed to literature development of organization and management in the area of creating effective organizational structures. The great importance is given to organizational culture, which consists of formal and informal structures being the effect of relationship types between participants of the system.

Literature review presents a various models of organizations, in which each of them uses different rules determining specific behaviour.

The bureaucratic model was created by Max Weber who was one of the main representatives of administrative direction of scientific work organization. His greatest achievement was the theory of authority and the concept of bureaucratic organization [7–9]. He distinguished three types of authority in formal organization and decided that each of them, for efficient operation, requires adequate administrative system, which the most rational form is bureaucracy characterized by a hierarchical organization structure, labor division within administration and stable regulations [10]. Analyzing this model from communication process point of view, it should be noted that direction of communication runs from up to down of organization structure, which means that superiors give commands, subordinates realize them and prepare proper statements and reports.

Human relationships model presents organization as a combination of formal and informal structures. Proposed by Henri Fayol innovative way of contact in hierarchical organization structure, called Fayol's Bridge [7–9, 11], rely on authorizing employees of various departments to communicate with each other in the less importance matters, without any formal way. Communication in this model runs in horizontal and vertical direction. The Fayol's Bridge was proposed to reduce communication time in organization and it is an exception from the hierarchy principle formulated by Fayol in 14 rules of management, basing on vertical communication.

Administrative model developed by H.A. Simon presents an organization as a complex network of communication processes. One of the element of the concept is a problem of connectivity in organizational system. The process of which is understood as a process transferring information between members of organization. Superiors and subordinates have got separate and clearly defined tasks and communication is two-way. Managers are focused on openness and feedback strategy towards subordinates.

Model Y, developed by McGregor, shows organization as a place of employees self-realize [12–14]. Managers assume that employees can be ambitious, have motivation, willingness to take responsibility, use self-control and act autonomously. The process of communication is from down to up, from employees to managers. Organizational model is characterized by a high flexibility for changes in such environment.

Likert's Model participative style [15] perceives an organization as a system of verbal communication, based on overlapping groups, called linking pins. There are interpersonal relationships and verbal messages preferred, and communication process takes place in all directions. The model characterized by a fact that a group of employees determine their own goals, take decisions by themselves, and manager usually accepts them. It is based on a full trust between manager and his subordinates leading to jointly manage a team. It becomes possible to create a highly flexible and efficiently functioning structure.

The template model is devoid of hierarchy and communication processes take place in all directions between members. This arrangement increases structure flexibility, better adjustment to the new conditions and better reactions to chaos and changes.

5 Process Diagram

Process diagram is design to present the chronology and logic way of activities performed in a process. It presents the structure of the process and relationships between its components in transformation of inputs into specific outputs. In diagnostic approach it describes an existing process, while in prognostic approach it becomes a tool for processes modelling. It is a starting point for analysis of processes and it illustrates process flow pointing executors of particular activities [16].

To present a sequence of activities in a form of flowchart which allows for better understanding an essence of the process, but significant role concerns preparation of the schema, because while creating the process there are discovered many dependencies [17].

This tool contributes also to improve its quality by reasonable adjustments, corrections and modifications [18].

There is no restriction in using flow diagram. It can be used in production processes, services or administration, that is why depending on needs and goal to be achieved, a block diagram can be a carrier of variety of information. Flow diagram can be a simple presentation of information which is sufficient for general process understanding or it may be multi-level developing of particular activities and decision points [19].

The flow diagram is usually used to describe existing process, to design new processes, to design improvements, as well as process analysis and visualize processes flow in enterprise.

6 Process Diagram of Data Input

This paper is focused on a problem concerning data input of a process diagram as a tool of improving internal communication in enterprise. The diagram, with clearly defined steps, describes the method of complete the IT system with technological, planning, manufacturing, purchasing, cooperative and controlling data, improving this way the communication process between various organizational units.

It can be distinguished the following phases of this method:

- preparation and input of technological data,
- manufacturing process design,
- purchasing and subcontracting data input,
- product structure creation (bill of material),
- production planning data input,
- verification of implemented data,
- execution of cost calculation.

The process of data input to production management system starts with preparation of technological data in design manufacturing processes department. These data are sent to product master database (PMDB) coordinator. The technological data are input to PMDB and then distributed to other IT systems transferring various types of data for master production scheduling system (MPSS), manufacturing system (MS) and customer service system (CSS) requirements. Next, PMDB coordinator informs departmental technologists about data distribution to MS. This runs the essence of the diagram, as a tool to improve communication process of data input to the system. Technologists begin their work in MS with design manufacturing process in form of defined technological operations and creation product structure. When product is produced from purchased material, than purchasing department inputs purchasing data to MS. Than production planner implements planning data, essential for correct scheduling production in the system. In next step, the administrator of the system, who is a coordinator of activities in the process, verify correctness and completeness of implemented technological, manufacturing, purchasing, subcontracting and planning data in order to send information to controlling department asking for executing cost calculation in MS.

The analysis of the process concerning data input to production management system provides knowledge about complexity of the process, involves many organizational units of the company. Quality of the communication process between organizational units determines correctness and completeness of implemented data. It is also an indicator of teamwork skills.

Algorithmic spin of data input process allows to create a block diagram showing the chronology and logic activities carried out in the process (Figs. 1 and 2). It shows process structure and relationships between its components. It becomes a general process model. It is starting point for detailed processes analysis within individual phases.

This diagram presents general steps and decision points necessary to execute by the individual organizational units in company, involved in the process by MS users as well. The idea of the process concerns understanding process essence, its improvement, and above all improve the quality of communication between the system users. In terms of usability it contributes to correct and complete the IT system with necessary data to execute cost calculation in MS.

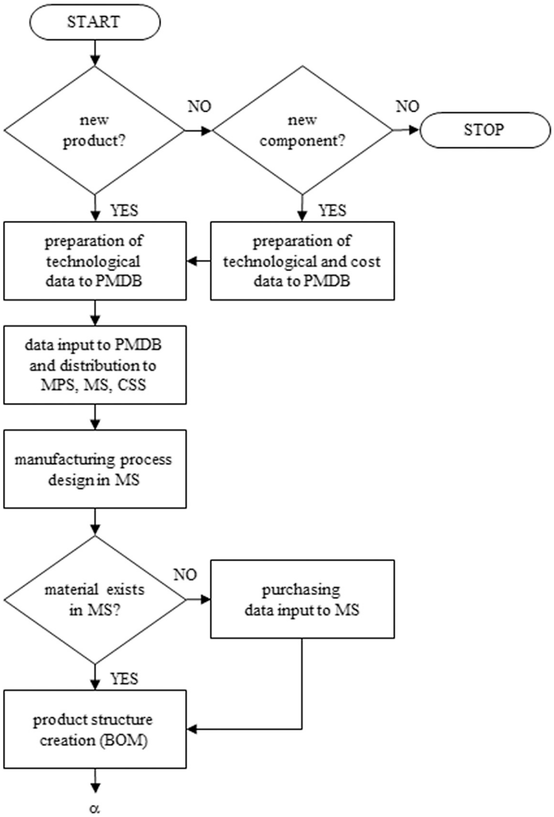

Fig. 1. General block diagram of data input to MS

Generally, functional approach of the block diagram gives a possibility for further detailed analysis of various activities executed in the process, thereby showing a kind of model of communication system in the company.

The process diagram of data input to MS begins with determining whether a new product or a new component has to be implemented. In case of a new product, department responsible of manufacturing process design, prepares technological data required for PMDB. At the same time, the department informs technologist of packaging who prepares data about method of packaging product. Data from the both sources, technological about product and packaging technology are transferred to PMDB coordinator, responsible for enter them to database.

When a new component has to be implemented to MS, then information of a necessity for technology data preparation goes to technologist appropriate department, where production of the new component will be launched. Now, technological data is transmitted to production department manager who prepares cost data for PMDB. Then the set of technological and cost data is sent to packaging technologist who prepares data about method of the component packaging and finally he enters the set of data to MS.

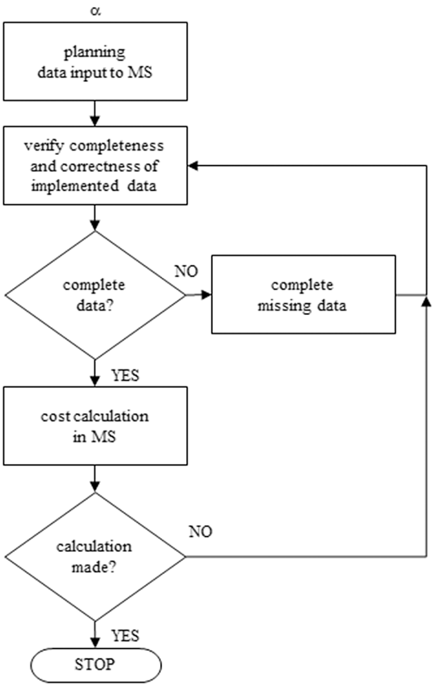

Fig. 2. General block diagram of data input to MS

In both described above cases there is packaging technologist who sends data to PMDB coordinator or implements data to database by himself. This division is dictated by a type of assortment – product or component.

PMDB coordinator enters the data to the database and distributes them to other IT systems: MPSS, MS and CSS. The same operation executes packaging technologist in case of new component. After the implemented data technologists of all departments have to be informed about data distribution to MS. Each department's technologist executes similar activities in MS, allowing to fill the system by data.

Because of large size of the process diagram of data input to MS, the paper will focus on a part of the diagram presenting certain activities concerning one production department which reflects essence of the whole process (Figs. 3 and 4).

Technologist of department producing a component X starts working in MS with design manufacturing process in form of defined technological operations and creation product structure (BOM) only when material already exists in MS.

In case when the component is produced from purchased material, and it does not exists in MS, then technologist informs purchasing department about a need to input missing material to the system. Purchasing specialist creates new material in MS and enters purchasing data, and then gives feedback to technologist, informs also planner and warehouseman. The situation may arise when technological operation has to be executed in other company, than subcontracting data have to be input to MS. This is also a task for purchasing department.

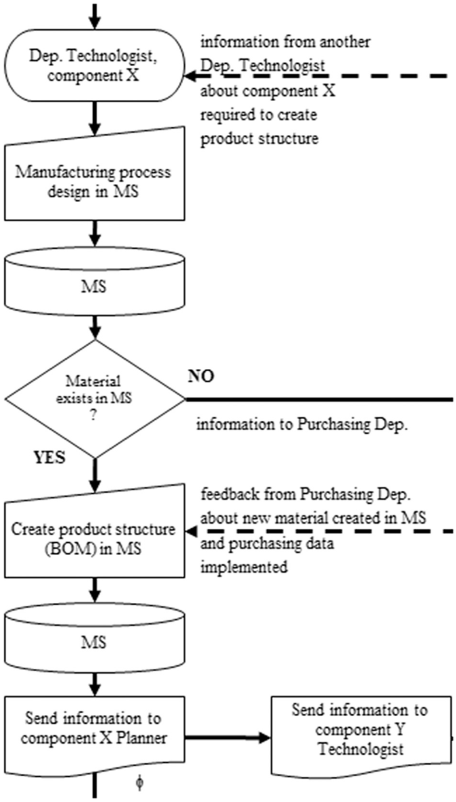

Fig. 3. Process diagram of data input to MS (technological and planning fragments)

After technological data input, department's technologist of component X informs another department's technologist about work completion in MS and available data necessary for him to start working.

Then the information from department's technologist goes to department's planner who inputs planning data required to proper production scheduling component. When finished, department's planner transmits information to MS administrator who is also a coordinator of activities related to the process of data input coming from various organizational units (departments) in order to verify completeness and correctness of implemented data from the system viewpoint that may send information to controlling department asking to execute cost calculation. In case of problematic situation, an appropriate organizational unit, responsible for technological, planning or purchasing data input, makes appropriate changes, corrections or additions of missing data.

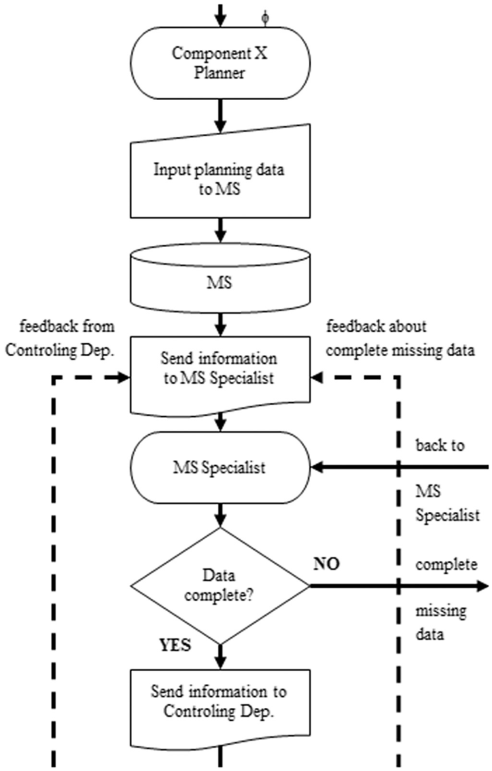

Fig. 4. Process diagram of data input to MS (technological and planning fragments)

7 Communication in Process Diagram of Data Input

System of communication in the process diagram of data input to MS corresponds to processes of communication at group level. Participants of the system are people who belong to various organizational units (departments) in the company. All of the process participants have got assigned duties which they execute to achieve objectives.

Interpersonal communication is related to information transmission from the process coordinator to team members, the process participants and the system users. Effectiveness of communication processes depends on style of communication and feedback. Each participant of the data input process has got precisely defined tasks and method of their execution.

Paying attention in the process of data input illustrated by the diagram on individuals involved in the communication process, a model of information system transfer can be obtained (Fig. 5).

The relationships between units designed in the model as design manufacturing processes department and packaging technologist are similar to the bureaucracy model because direction of communication runs from up to down of the organizational structure, it means superior (design manufacturing processes department) gives a

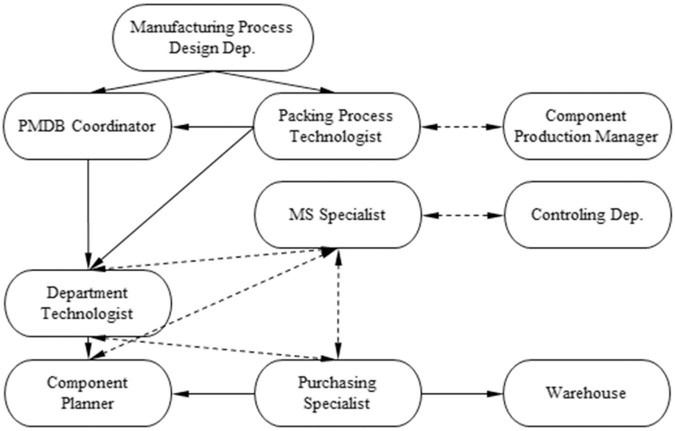

Fig. 5. Model of communication system in process diagram

command and subordinate (packaging technologist) executes it. This is the only formal structure in the process of data input.

In the most of communication cases, the human relationships model appears in which individuals – participants communicate directly one with one another, omitting the person coordinating activities in the process, which significantly reduces the time and way of communication. Information transmission takes places between equivalent units in hierarchy of formal organizational structure: packaging technologist and department's technologist, department's technologist and department's planner, purchasing specialist and department's planner, purchasing specialist and warehouseman or between units equivalent only in informal structure of the process of data input: packaging technologist and component production manager, PMDB coordinator and department's technologist, packaging technologist and PMDB coordinator.

The analysed model of information system transfer also shows similarities to the administrative model, presenting organization as a complex network of communication processes. The communication is two-way: between packaging technologist and component production manager, MS specialist and controlling department, department's technologist, purchasing specialist and department's planner, department's technologist and purchasing specialist.

Participants of the process of data input have responsibility for quality of implementation data and motivation to act. They are aware that next process steps depend on tasks executed by them. So, they work autonomously without control from management side. It can be find there elements of the model Y.

It should be noticed that participants of the process create, during data input, informal structure with functionally different organizational units. Control of the whole process exercises a person called MS specialist, who plays a leading role.

The above considerations on similarity of the analysed model of system information transfer to one of the literature's models, lead to conclusion that the analysed model is not homogeneous throughout its structure because individual parts contain features of various literature's models. One can say that it is a hybrid model of communication.

Appropriate organizational communication process and interaction are necessary conditions in a process of combining knowledge and skills in a functional wholeness which encourages innovation, knowledge development and implementation of effective mechanisms of organization functioning [20].

8 Conclusions

A subject of the paper is a process diagram of data input to IT system as a tool to improve communication process inside company.

Observational research as well as reports of errors and missing data created for administrator of IT production management system were carried out under real conditions of company of producing machine parts. These research provided with the knowledge about quality of communication between various organizational units (departments) within the company and between the IT system users as well.

The diagram presented in the paper, with clearly defined steps, specifies method of completing the IT system with technological, planning, manufacturing, purchasing, subcontracting and controlling data, improving this way an internal communication process.

The diagram presents chronologically and logically organized activities, executed in the process. It shows the process structure and relationship between its components.

There are two approaches to the diagram presented in the paper: diagnostic, describing an existing and applied under the real conditions the process of data input to the IT system, and the second one – prognostic approach, which is a tool of communication system between units (departments) in modelling process.

Visualization of the chain of actions as the diagram process allowed to understand better essence of the process, also subject, functional and communication dependencies occurring between the IT system users as well as it realized an importance of the communication process.

Analysis of the process transferring information between organizational units (departments, people) the above consideration data input process, led to define the model of communication system as a hybrid model containing features of various literature's approaches.

References

1. Dobek-Ostrowska, B.: Podstawy komunikowania społecznego. Astrum, Wrocław (1999)
2. Cooley, Ch.: Social organization, New York (1909)
3. Schramm, W.: Man, messages and media, New York (1973)
4. Goban-Klas, T.: Komunikowanie masowe, Kraków (1978)
5. Verderber, R.: Communicate!, Belmont (1993)

6. Adamczyk, M., Jurga, A., Kałkowska, J., Pawłowski, E., Włodarkiewicz-Klimek, H.: Projektowanie systemów informacyjnych zarządzania. Wydawnictwo Politechniki Poznańskiej, Poznań (2010)
7. Martyniak, Z.: Metody organizowania procesów pracy. PWE, Warszawa (1996)
8. Koźmiński, A.K. (red.): Zarządzanie. Teoria i praktyka. PWN, Warszawa (2004)
9. Bieniok, H. (red.): Podstawy zarządzania przedsiębiorstwem. PWE, Katowice (2005)
10. Zieleniewski, J.: Organizacja i zarządzanie. PWN, Warszawa (1969)
11. Koźmiński, A.K., Jemielniak, D.: Zarządzanie od podstaw. Wolters Kluwer, Warszawa (2011)
12. McGregor, D.: The Human Side of Enterprise. McGrawHill, New York (1960)
13. Sahin, F.: The mediating effect of leader-member exchange on the relationship between Theory X and Y management styles and effective commitment: a multilevel analysis. J. Manage. Organ. **18**(2), 159–174 (2012)
14. Sager, K.: An exploratory study of the relationships between Theory X/Y assumptions and superior communication style. Manage. Commun. Q. **22**(2), 288–312 (2008)
15. Modaff, D.P., Butler, J.A., DeWine, S.: Organizational Communication: Foundations, Challenges, and Misunderstandings (Third Edition), pp. 59–62. Pearson Education, Glenview (2008)
16. Hamrol, A.: Zarządzanie jakością z przykładami. PWN, Warszawa (2005)
17. Hamrol, A., Mantura, W.: Zarządzanie jakością. Teoria i praktyka, PWN, Warszawa (2002)
18. Ładoński, W., Szołtysek, K. (red.): Zarządzanie jakością. Wydawnictwo Uniwersytetu Ekonomicznego, Wrocław (2008)
19. Łucza, J., Matuszak-Flejszman, A.: Metody i techniki zarządzania jakością. Kompendium wiedzy. Quality Progress, Poznań (2007)
20. Trzcieliński, S., Włodarkiewicz-Klimek, H., Pawłowski, K.: Współczesne koncepcje zarządzania. Wydawnictwo Politechniki Poznańskiej (2013)

A Study of the Analysis Framework to Construct the Mechanism Model of Intellectual Productivity Changes Affected by Workplace Environment

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Abstract. Many companies have been working on to reduce energy consumption these days. However, it could also reduce efficiency of office work because the office environment becomes uncomfortable by the energy saving. Thus, it is necessary to save energy and keep workplace productivity at the same time. Since quantitative analyses about certain effects of workplace environment to office productivity have been already done in conventional studies, the degree of each environmental effect can be compared. It is however unclear how the environmental condition affects their productivity. The purpose of this study is to propose a systematic combination of various expert statistical methods as a framework of mechanism analysis of productivity changes. The proposed framework was also tested by case studies of some different varied environmental factors.

Keywords: Workplace productivity · Analysis framework · Indoor environment

1 Introduction

Energy consumption on business sector has kept increasing recently especially in Japan, and many company have been working on reducing energy consumption in their office places, such as reducing air conditioner use, thin out lightings and so on. However, those activities of reducing energy consumption could make their office environment uncomfortable and it may bring negative effect to the workers' intellectual productivity, which means workers' efficiency of intellectual work. Therefore, it is necessary to design the office environment not only to reduce energy consumption but

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also to keep their intellectual productivity. Thus, to improve office environment in such effective way, it is required to reveal not only the variation of productivity itself but also the mechanisms of productivity changes caused by environmental factors.

Since quantitative analyses about certain effects of workplace environment to office productivity have been already done in conventional studies [1–3]. the degree of each environmental effect can be compared. However, it is necessary to measure varied factors and their varying process leading to productivity change in order to reveal the essential relationship between environmental factors and productivity changes. On the other hand, some conventional studies have focused on the varying workers' state that leads to productivity changes [4]. In light of these studies, the degree of varying workers' state can be compared however the degree of productivity changes remains conjectural. In this way, there are few studies analyzing the mechanisms of productivity changes that are brought by the environmental changes.

The purpose of this study is to propose a systematic combination of various expert statistical methods as a framework of mechanism analysis of productivity changes. The proposed framework was also verified by case studies of some different varied environmental factors. In this study, a general mechanism model including every element of productivity changes and a procedure to quantify the changing mechanisms were proposed as an analysis framework. The quantification procedure is composed of measuring methods of the elements of general mechanism model and statistical process of measured data. Some serviceable approaches were also proposed in each process.

2 Proposed Analysis Framework

Figure 1 shows the whole DFD (Data Flow Diagram) of the proposed analysis framework. This framework returns a quantitative mechanism model of productivity changes when analyst inputs certain environmental factors. The quantitative mechanism model shows the strength of causal relationships between productivity changes, a focused environmental factor and each element of varying productivity. These elements are described in the general mechanism model. According to Petra [5], it is necessary for measuring the effect of varying workplace environment on intellectual productivity to make a model that describes any factors that affect intellectual productivity. Therefore, this proposed analysis framework is composed of the general mechanism model and the quantification procedure. The general mechanism model includes whole elements of varying productivity and shows causal relationships between environmental changes and productivity changes through those varying elements. Thus, even if there are no hypothesis how a certain environmental change effects, the model realizes the exploratory data analysis to find which factor is important in the analyzed situation. The quantification procedure is composed of whole analysis processes not only the statistical method but also the data measuring method and data processing before the statistical analysis. This method quantifies the strength of passes between component elements of the general mechanism model.

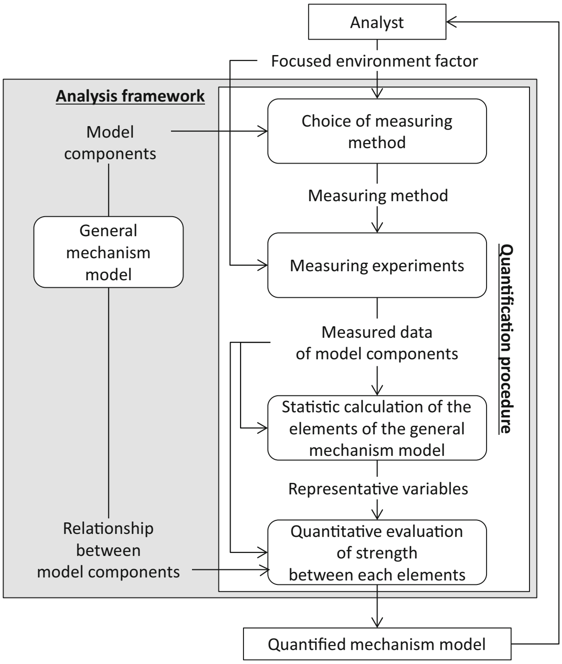

Fig. 1. Full DFD of proposed analysis framework.

2.1 General Mechanism Model

On account of Woods [6] and Swan [7], this general mechanism model shows that tit is created from the idea that the environmental change affects internal state factors and the result of the internal state factors changes, the productivity varies. In addition, some individual traits that could affect their internal state factors are included such as sensitivity to heat and cold, dry eyes. In this paper, productivity is defined as work efficiency, so according to Kato [8], it is the ratio of intellectual work progress (output) to working time (input). Therefore, the general mechanism model is defined as shown in Fig. 2.

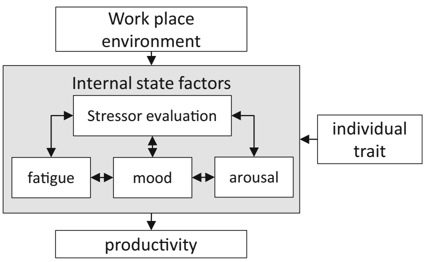

Fig. 2. The general model employed in the proposed framework.

Here, workplace environment is defined as a certain factor that can affect progress of knowledge processing. Knowledge processing is one of the layers of intellectual work proposed by Murakami [9], which includes work to be done consciously and not includes some creative work such as idea creation. Office work considered in this study therefore does not include other layers, the information processing layer whose work is done unconsciously and the knowledge creation layer. For example of the environmental factors that affect knowledge processing work progress, Mendel [10] focused on the air quality, room temperature, sound environment, individual controllability and lighting environment, and Wyon [11] showed that many experts regard these factors important.

The internal state factors here consist of stressor evaluation, fatigue, mood and arousal. According a conventional study [12], the four factors are defined; stressor evaluation is defined as individual feeling and unpleasantness about the workplace environment; fatigue is defined to include both physical and mental fatigue caused by doing intellectual work; mood is defined as a static emotional state that affects workers' productivity during interaction with their cognitive processor; and arousal is defined as a conscious state of stimulated central nervous system and wide-awaken which can have important influence on productivity from the viewpoint of attention on their work.

In this model, individual trait means some permanent characters that could not be affected by environmental change nor any varying factors. It includes demographic items, such as gender, age, family size and income, basic individual characters such as lifestyle and sense of values, standard values, and sensitivity of environment. Since these individual traits may have influences on whole the mechanism model, they should be referred when analysts want to classify analysis participants into some groups based on common characteristic.

2.2 Quantification Procedure

The quantification procedure derives a quantified mechanism model when analysts input some workplace environmental factors and elements of the general mechanism model and their relationships. The procedure includes measuring the elements of general mechanism model and statistical process of measured data.

The analyst first chooses the measuring method of model components that may be affected by the focused environmental factor. Although some serviceable approaches are proposed in each process in this study, it is not necessarily to choose the method from conventional studies. Any suitable method including both new and old can be chosen depending on the situation. To get enough amounts of measuring data, how many data measured per a worker or per time, in other words, the time resolution and the simultaneous measurement feasibility, have to be considered.

Some typical examples of measuring productivity are cited as follows; one method is to use performance records of cognitive tasks, including answering time per question and error rates. Although it has a good time resolution, its results might be affected by leaning effect during measurement. The learning effects is neglectable by using CTR (Concentration time ratio), developed by the authors based on the hypothesis that intellectual works proceed only when workers concentrate on their works. There are also some methods conducted without any PCs, like the subjective productivity

Table 1. Examples of serviceable measuring method of intellectual productivity.

Measuring method	Time resolution	Simultaneous measurement feasibility	
Records of cognitive tasks	In minutes	One measuring PC to one participant	Learning effect has to be considered
CTR (Concentration time ratio)	In one task set (about 30 min)	One measuring PC to one participant	
Subjective productivity assessment	In one task set	Questionnaires	

assessment that is adaptable to various kind of tasks [13]. The objective time resolution and simultaneous measurement feasibility of those methods are shown in Table 1.

As examples of measurement of the arousal of internal states factors, UMACL (UWIST mood adjective checklist) [14], eye movement measurement and electroencephalogram measurement can be employed. UMACL is a general questionnaire used in broad field of studies, however enough amount of data has to be collected for factorial analysis. Eye movement measurement and electroencephalogram measurement are physiological indices and they are more objective than questionnaire survey, however it is necessary to prepare special measuring instruments for the numbers of participants.

As examples of measuring the fatigue of internal states factors, subjective symptoms check [15], eye movement measurement and heart rate variability. Subjective symptoms check is a simple questionnaire set used in many conventional studies, including the questions of checking recent days' working situation. The eye movement measurement and the heart rate variability are physiological indices so that they are objective. In addition, they are also often used because they are one of the standard instruments. The measurement instruments can be shared with arousal measurements, like eye movement measuring instruments can measure pupil diameter for fatigue and eye blink for arousal, and measuring instruments of biological signal can measure electroencephalogram for arousal and electrocardiogram for heart rate variability to estimate fatigue.

As an example of measurement of the mood of internal state factors, MMS (multiple mood scale) [16] is recommended. MMS is a questionnaire which consists of versatile questions. Here, no physiological index is recommended, because there is no established physiological index to measure mood, long-term varying mental state.

As examples of measurement of the stressor evaluation, SAP (the subjective assessment of workplace productivity) [17] and subjective evaluation of workplace environment can be employed. SAP is a questionnaire developed by summarized relevant studies of stressor evaluation, so that it can be used in wide fields. The subjective evaluation is a set of specific questions that analyst made in each experiment. If the analyst has some hypothesis of the varying mechanisms of productivity by environmental change, the subjective evaluation method is effective and easy to conduct.

As examples of measurement of individual traits, demographic characteristics questionnaire, workplace preference questionnaire and the morningness - eveningness check [18] are suggested. The measured values are standardized based on the average and the distribution of all the individuals in order to clearly express the difference.

In actual measurement experiments, in addition to conduct the measurements correctly, it is necessary to consider how to avoid influence caused by the unintentional factors except the focused environmental change, such as learning effects and order effects. Thus, certain countermeasure should be taken such as taking counterbalance on experimental periods, consequences of experimental condition and participants' traits.

2.3 Statistic Calculation of Measured Data and Quantitative Evaluation

Statistic calculation of the measured data is necessary step for the following quantitative analysis. Whole four steps are recommended to execute from the top to the bottom of Table 2.

Table 2. A list of statistic calculation method and information of when to apply it.

Method	When to apply
Normalization	When parameters are thought to be composed of variant with different relative amount or different meaning of absolute content
Factor analysis	When there are too many parameters to analyze and consider explanatorily
Clustering analysis	When the slicing steps become too complex by unorganized variables
Decision tree analysis (Regression tree analysis)	When analysts need to classify the analyzed objects into more suitable groups of similar individual traits

After these static calculations, the strength between calculated elements of model are quantified by using covariance structure analysis, Bayesian network analysis and correlation analysis. In order to execute covariance structure analysis or Bayesian network analysis, it is necessary to prepare many data to discuss based on statistic significant level. Correlation analysis is somewhat easy to use because it doesn't need many data, but it can't analyze the significant differences between relationship of factors. Therefore, it is recommended to choose the suitable analysis method along with the experimental purpose.

3 Case Studies

The framework was tested by case studies of three different varied environmental factors; experimental data of productivity changes affected by (1) illumination environment, (2) airflow environment and (3) multiple controlled environmental elements. Details of experiments are shown in Table 3.

Table 3. Details of case study experiments.

	Experiment (1)	Experiment (2)	Experiment (3)
Conducted date	2013/7/29–2013/9/5 4 day experiment	2014/8/4–2014/9/6 (summer) 2014/12/20–2015/1/22 (winter) 3 day experiment	2 day experiment
Participants	24 participants Age 30–50 12 females/12 males	56 participants Undergraduate or graduate students 30 females/26 males	20 participants Working adults
Environment	N-TA lighting Vs. neutral	Airflow Vs. neutral	Multiple good Vs. neutral
Whole samples	24 × 6 = 144 samples	56 × 6 = 336 samples	20 × 3 = 60 samples
Productivity measurement	CTR (using receipt classification task)		
Other measurement	(1, 2) Subjective symptoms check (fatigue) (1) MMS (mood) (1, 2, 3) Subjective questionnaire (stressor evaluation) (1, 2) Demographic characteristics questionnaire (individual trait)		

Results of mechanism analysis are shown in the following figures. First we analyzed the mechanism model using whole participants' data, then analyzed two additional mechanism models, using classified participants' data, which are improved/not-improved productivity group, high/low productivity group, or merely females/males.

Figure 3 shows the results of analysis on experiment (1), which focused on illumination environment. Based on the analyzed mechanism model, the proposed illumination condition improved "energetic" factor and "freshen" factor, then these factors caused productivity improvement in case of the participants whose productivity improved under the proposed illumination condition. However, there was no path connected with "energetic" factor in case of participants of not improved productivity group. This analysis result shows the basic mechanism to improve the productivity and also explains the reason of different effectiveness between participants.

Figure 4 shows the results of analysis on experiment (2), which focused on airflow environment. Results shows that productivity improvement was made by the proposed environment through temperature feeling, airflow feeling, blur and drowsiness. It shows that the factor of airflow feeling has both positive and negative effect on the experimental results. Especially for example of participant of high productivity group, airflow sometimes disturbed participants' concentration. Therefore, the results show that it is necessary to modify the proposed airflow not to disturb participants' concentration.

Figure 5 shows the results of analysis on experiment (3) which was conducted under multiple controlled environment. Based on the result, greatly different mechanism could be found between females and males. Especially about the room temperature, the effect came out in different way on productivity changes, which must be

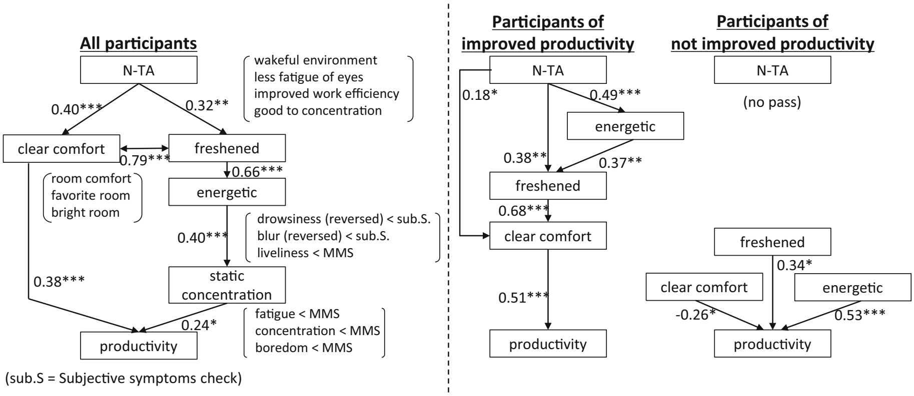

Fig. 3. Analysis results of case study experiment (1).

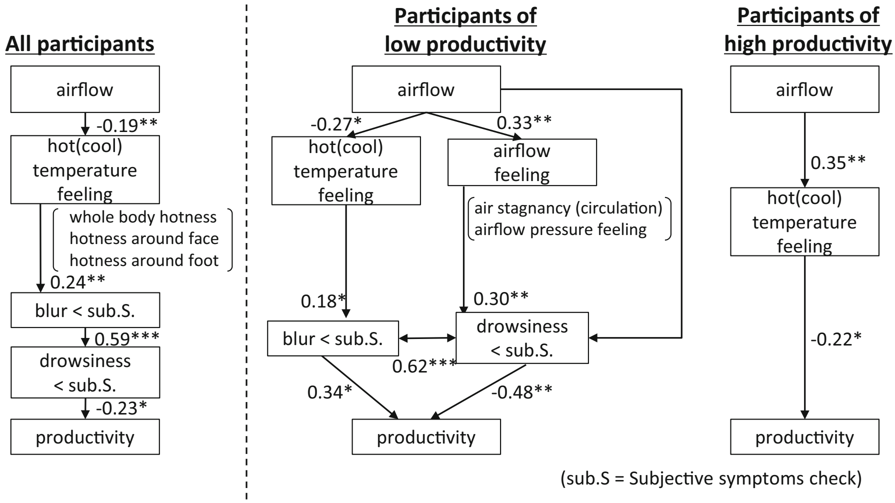

Fig. 4. Analysis results of case study experiment (2).

considered carefully when designing office environment. On the other hand, factors of environmental preference had no effect on productivity, so that it is not important to consider the environmental preference to design high-productivity workplace.

Like the above, some improvement plans to realize high-productivity workplace environment could be also proposed by using the results of framework analysis and some important point to be considered when designing the office environment were found by the mechanism model. Moreover, especially when classifying the data into a group of improved productivity and a group of not-improved productivity, each group had its own mechanism of productivity improvement or reduction. Therefore, it was confirmed that the framework could interpret productivity changes by the change of workplace environment without contradiction.

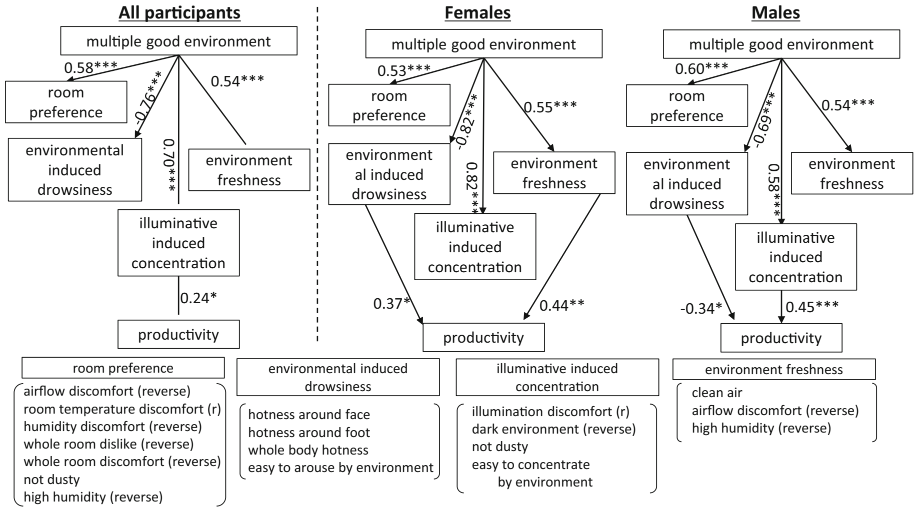

Fig. 5. Analysis results of case study experiment (3).

4 Conclusion

In this study, a systematic combination of various expert statistical methods as a framework of mechanism analysis of productivity changes was proposed. It was also tested through case studies of some different varied environmental factors. It was confirmed that the framework could analyze the mechanisms of productivity changes without contradiction, and it also could suggest some improvement plans of workplace environment.

In further study, it is required to measure both the productivity changes and the overall elements of general mechanism model and to analyze them with the proposed method as a case study in order to improve the proposed analysis method.

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References

1. Wargocki, P., Wyon, D.P., Fanger, P.O.: Productivity is affected by the air quality in oces. In: Healthy Building 2000, pp. 635–640 (2000)
2. Fisk, W.J., Price, P.N., Faulkner, D., Sullivan, D.P., Dibartolomeo, D.L., Federspiel, C.C., Liu, G., Lahi, M.: Worker performance and ventilation, Part 1 and 2. In: Proceedings of Indoor Air 2002, pp. 784–795 (2002)
3. Kroner, W.M., Stark-Martin, J.A.: Environmentally responsive workstation and worker productivity. ASHARE Trans. **100**, 750–755 (1994)
4. Tanabe, S., Nishihara, N.: Productivity and fatigue. In: Indoor Air 2004, pp. 126–133 (2004)
5. Bosch-Sijtsema, P.M., Ruohomaki, V., Vartiainen, M.: Knowledge work productivity in distributed teams. J. Knowl. Manag. **13**(6), 533–546 (2009)

6. Sensharma, N.P., Woods, J.E.: An extension of a rational model for evaluation of human responses, occupant performance, and productivity. In: Healthy Building 2000, Workshop 9 (2000)
7. Swain, D.: Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, U.S. NRC, pp. 51–76 (1983)
8. Kato, H.: Is the aging of society a threat to japan?; increasing productivity in the next decade is the key. National Institute for Research Advancement (NIRA) Report 2009.11, pp. 9–10 (2009)
9. Murakami, S.: Purpose and framework of research on intellectual productivity. The 2nd Reports of the research committee of intellectual productivity, No. 5, 17 Mar 2008
10. Heath, G.A., Mendell, M.J: Do indoor environment in schools influence student performance a review of the literature. In: Indoor Air 2002, pp. 802–807 (2002)
11. Wyon, D.P., Fisk, W.J.: Research Needs and Approaches Pertaining to the Indoor Climate and Productivity, Healthy Building 2000 Workshop Summaries (2000)
12. National Institute of Advanced Industrial Science and Technology, Human Welfare Biometric Engineering: Human Measurement Handbook. Asakura Publishing Co., Ltd. (2003)
13. Sugiura, T., Hashimoto, T., Terano, M., Nakamura, M., Kawase, T., Kondo, Y.: Evaluation method of work place productivity, the first report – Organizing productivity evaluation methods and suggestion of the standard methods. Academic lecture papers of The Society of Heating. Air-Conditioning and Sanitary Engineers of Japan, 123, pp. 11–22 (2007)
14. Matthews, G., Jones, D.M.: Refining the measurement of mood: the UWIST mood adjective checklist. Br. J. Psychol. **81**, 17–42 (1990)
15. Japan Society for Occupational Health: Handbook of Productive Fatigue (1988)
16. Terasaki, M., Kishimoto, Y., Koga, A.: Construction of a multiple mood scale. Jpn. J. Psychol. **62**(6), 350–356 (1992)
17. Hashimoto, S., Terano, M., Sugiura, T., Nakamura, M., Kawase, T., Kondo, Y.: Productivity gains from better indoor environmental quality. Transactions of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, vol. 93, pp. 67–76 (2004)
18. Ishihara, K., Miyashita, A., Inugami, M., Fukuda, K., Yamazaki, K., Miyata, Y.: The results of investigation by the Japanese version of Morningess-Eveningness questionnaire. Jpn. J. Psychol. **57**, 87–91 (1986)

Workplace Violence: The Change Laboratory as a Tool for Expansive Learning in the Activity of Social Reintegration of Adolescent Offenders

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Abstract. This article addresses the issue of the physical and mental violence suffered by socio - educational support agents who provide services at the CSAA Foundation - Unit Campinas. The methodology applied will be that of the Change Laboratory – CL, a Finnish method of training for intervention that assists in the development of work activities with the presence of professionals who collaborate with the researchers-interveners. Applied in several countries, it is a toolbox for designing and testing new forms of work through the expansive learning of the object based on the dialectic of the ascension from the abstract to the concrete. Thus far, field visits have been carried out to conduct interviews and routine observation as well as the analysis of institutional documents. The research is in the phase of the systematization of the data so that in the coming months the CL sessions may begin.

Keywords: Violence at work · Socio-educational support agents · Change Laboratory

1 Introduction

The following passage from a newspaper report describes one of the forms of violence present in the daily routine of the workers and trainees of the Center for the Socio-educational Attendance on the Adolescent – CSAA Foundation – Unit Campinas.

"One adolescent and at least two of the staff of the CSAA Foundation were wounded this Tuesday afternoon (13), during a riot in the San Martin suburb, in Campinas (SP). The situation was brought under control by about 16h. The building is located beside the unit where a rebellion occurred on Monday night" [1].

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Violence is a social question and a theme on the national and international public agenda. One must, in dealing with its historical development, highlight its transfer to the field of public health in the course of the immensely complicated discussion [2]. Violence has been defined by the World Health Organization as the "intentional use of force or power in the form of threat or effective action against oneself, another person or group or community, which causes - or is highly likely to cause - wounds, death, psychic harm, alterations in development, or privation" [3].

The debate on the various forms of violence is closely related to the directives emphasized by the international human rights organizations[1], which give priority to the protection of life, guaranteeing dignified conditions of survival for all its subjects in such a way that their basic needs shall be safeguarded.

Within Brazilian history, violence has been a resource widely exercised by the dominant classes for the maintenance of the social organization. Violent practices have been included in the politics of prevention since the founding of the State, and have been manifested in various contexts, social, domestic and labor [4].

Workers may be exposed to various forms of violence including the physical, the psychological, the sexual, and to that constituted by the neglect of the preservation of their health and life, affecting their dignity by moral harassment and other manifestations which put workers' mental health at risk when there is a lack of affective and social support [5].

In the total institutions[2] of the CSSA Foundation type, there exists a basic division between the great controlled mass, which we might call the group of internees, and a small supervising team. Both these groups tend to conceive the other in terms of limited and hostile stereotypes – the managing team often see the internees as bitter, reserved and unworthy of confidence: the internees often see the managers as condescending, arbitrary and mean [6].

However, it is not just between these two poles that the dynamics of this institutional service is constructed. Among the internees, the daily co-existence for long periods leads to the creation of relationships and establishes links, leading to the organization of groups which work with their own rules and make the life of these establishments still more complicated [7].

This disparity among the actors is reflected in some of the conflicts which exist in the CSSA Foundation in Campinas, where a privileged position can, in itself, create a distance between the groups which live together in the institution, leading to situations of violence which affect both the workers and the internees, as is exemplified by the rebellions and mutinies mentioned. Further, according to the authors, for the members of these two categories (internees and agents), the risks to their personal well-being are

[1] Especially, for the Brazilian case, the integrating organisms of the so-called Global or universal system of human rights, constructed by the United Nations Organization (UNO), and those which constitute the Inter-American Regional System for the Protection of Human Rights, under the aegis of the Organization of American States (OAS) [8, pp. 239–242].

[2] A total institution is a place of residence and work where a large number of persons in a similar situation, separated from the wider society for a considerable period of time, lead a restricted, formally administered life.

among their leading concerns and are strongly marked by the relationships both formal and informal which regulate their life in the institution [6, 7].

2 Brief History of the CSSA Foundation

The units of attendance to the adolescent in the State of São Paulo were, until the end of 2016, called The State Foundation for the Well-being of the Minor (FEBEM). FEBEM then adopted the name CSSA Foundation sanctioned by State Law 12.469/2006, which, among other dispositions, determined the alteration of the name of the organization, as also the method by which the minors were assisted, incorporating into its program actions of a socio-educational character for their rehabilitation and reintegration into society [9, 10].

The change of name and method was motivated by a decision of the InterAmerican Court of Human Rights (Court IDH)[3] against the Brazilian State, which accepted a request for provisional measures formulated by the InterAmerican Commission of Human Rights (ICHR)[4], which sought to protect the lives and the physical integrity of the children and adolescents interned in the Tatuape Complex of the then FEBEM for the improvement of the conditions laid out by the determinations of the Statute of the Child and Adolescent (ECA).

The ICHR reported to the Court IDH situations relating to fights between internees, floggings, occurrences involving torture, and riots which occurred frequently and which were not mediated proactively by the State. During the period of the investigation, the deaths of four internees were registered, as well as numerous riots and attempted mass escapes, often involving the capture and torture of the workers. A Report drawn up by the ICHR demonstrated that the whole Complex suffered from grave problems of overcrowding and of deficiencies in hygiene and health care, and that the adolescents did not have regular access to education, work or social reintegration measures.

With this, the Court accepted the request presented and required that the Brazilian State adopt, immediately, such measures as might be necessary to protect the life and personal integrity of all the children and adolescents who resided in the Tatuapé Complex, as well as of all the persons who were inside the establishment [11, p. 9]. There thus occurred an ample reformulation of the policy of the assistance given by the

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[3] A Court with competence to judge cases of the violation of Human Rights, integrated into the InterAmerican Regional System for the Protection of Human Rights. The IDH Court, with its head-office located in San José, Costa Rica, is an autonomous legal entity, created by the American Convention on Human Rights, approved in 1969 by the member states of the Organization of American States (OAS).

[4] The ICHR, headquartered in Washington, USAQ, is the maximum organ of the OAS in the field of the protection of human rights—also integrated into the Inter-American system of protection —, seeking to fulfill the Inter-American norms relating to the subject before the countries of the continent, having the legal status, in the fulfillment of this mission, to propose legal actions to the Inter-American Court of Human Rights. The request for provisional measures is one means of action of a cautionary and tutelary character, appropriate in cases which involve the seriousness, urgency and risk of irreparable damage.

Institution in the quest for more humanitarian treatment with a view to restoring the tarnished institutional image and avoid future denunciations.

The approval of State Law 12.469/2006 sought to adapt to the directives of the Institution the norms established by the Statute of the Child and Adolescent (ECA) of the National System of Attendance on the Adolescent (SINASE) and of the public policies for the reorganization and decentralization of the assistance given, a change begun in 1999 and constituting an initial landmark in the process of the restructuring, modification and amplification of FEBEM. In 2001, new units were inaugurated in some municipalities of the interior of the state of São Paulo, each with places for 72 adolescents. In 2006, further new units were presented, but with some alterations in their physical structure and administrative model [12]. At the present time, there are one hundred and fifty centers for socio-educational attendance in the State of São Paulo.

3 The Center of Socio-Educational Attendance on the Adolescent – CSAA Foundation – Unit Campinas

The CSAA Campinas is situated in the Matão suburb, on the boundary between the cities of Campinas and Sumaré. The Center for Attendance can house 56 adolescents of the male sex in the age range between 17 and 20 years and 11 months of age according to the Socio-Educational measures of internment as set out by the ECA directives [13, article 122].

The characteristics of the internees may be classified as follows: those who are included in the initial program of internment for internees with structured criminal experience; adolescents who have fulfilled their provisional internment; adolescents who have already fulfilled the program of supervised liberty; adolescents who have fulfilled their sentence, or youths who have already fulfilled a program of internment in the Centre itself or in the CSAA Maestro Carlos Gomes [12].

3.1 The Work Activity of the Socio-Educational Agents

The socio-educational support agents are qualified professional staff who undertake to accompany the internees in all the planned activities of the CSAA Campinas. Before the institution's change of name, the same professional personnel only exercised the function of surveillance, were called "monitors" and supervised only the discipline and order in the units [14].

The pre-requisite for the position is complete intermediate schooling. Some of the socio-educational support agents have exercised previous professional activity in the field of private security and/or worked in the police or served in the army. The majority of those interviewed have two or more jobs, which is also true of the nursing professionals who fulfill the same daily work-routine (working 12 h a day for two days and having the following two days off).

In accordance with decisions of the Sinase (2012), in agreement with the Statute of the Child and the Adolescent (2008) and of the bye-laws of the CSAA Foundation – SP [15], these professionals have come to assist/accompany the adolescents in the fulfillment of their socio-educational activities. These professionals did not, however, cease to exercise their function as inspectors. The reformulation of the activity, for the purpose of strengthening the ties between employees and internees, did not involve any change in the disciplinary role which these professionals exercised, culturally conditioned to acting in a police role. They, therefore, continued to search the internees with each change of situation within the Center, hindering the deliberate changes proposed by the directives of the institution, thus making the development of new roles in the relationships between the actors impossible.

4 Objectives of the Research

The objectives of this research project are: to become acquainted with the work activity of the socio-educational support workers/agents of the CSAA Foundation – Unit Campinas; to identify the determining factors of the health-disease/accidents process; to promote discussion which would reveal the workers' perception regarding the difficulties experienced in their activity, as well as the possible solutions and innovations necessary to overcome them; and to reformulate the system of activity in such a way as to share it between the actors of the institution, with the mediation of the researchers.

5 Research Methodology

The Change Laboratory (CL) is a Finnish method of formative intervention which assists in the development of work activities in the presence of professionals who work together with the researcher/interventionist. Applied in various countries, it consists of a set of tools for conceiving, projecting and testing new methods of work by means of expansive apprenticeship of the object under study based on the dialectic of ascension from the abstract to the concrete [16].

The process of apprenticeship adopted by the Change Laboratory - CL takes as its frame of reference the theory of cultural historical activity, the theoretical legacy of Lev Vygotsky and Alexei Leontiev: after having been duly adapted to work situations by Yrjö Engeström, the method calls for cognitive tools which will assist in the identification of the systemic causes of the labor conflicts lived, throughout history, by workers, as well as the disturbances to be mapped and conceived as contradictions internal to the structure of the activity, making the collective construction of new forms of work possible [17, 18].

For the purpose of mapping the contradictions which permeate organizational structure, it is necessary to examine the institutional changes which have taken place over time. The theoretical unit of analysis is represented graphically by a triangle, demonstrating the basic relationships existing in the systems of mediation of a human activity, thus proposing an Activity System (Fig. 1) which incorporates the unit for the understanding of human actions performed in the present and the past and how they might be remodeled in the future [19].

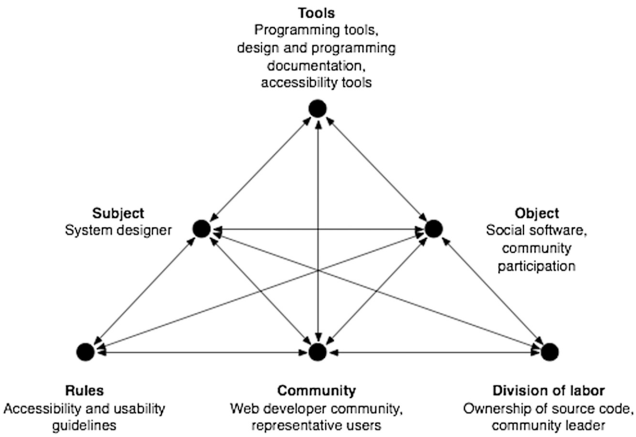

Fig. 1. Activity system

5.1 Stages of the Change Laboratory (CL)

The CL sessions began with an analysis of disturbances, identifying the systemic causes of the problems observed which express the contradictions inherent in or between the systems of activity. During the CL sessions, the participants produced a future vision of the activity, which is not only based on a classification of what one does or does not desire. In the CL the vision is based on an analysis of the structure of the activity which might help to solve the internal contradictions of the system in question [18, p. 623].

In the process, the professionals and the managers of the unit work intensely, together with a small group of intervention researchers, during a number of sessions (generally, some 10 to 12 sessions are held, each lasting 2 h) for the purpose of analyzing and specifying the challenges in undertaking the activity, and after the implementation of the new model, several follow-up sessions should be held to reassess and remodel the activity, as may be necessary [17].

The interventions begin with the collection of data on: (1) the situation of the activity, such as, historical data on important events; (2) present practices (the way in which the activity is conducted); (3) the main problems faced, and (4) the main concepts and tools used in the activity. The function of these data is a double one: to serve as data to be used during the sessions as a mirror of the activity to help the interventionist to understand the activity and guide the learning process.

The Change Laboratory process may be divided into seven main stages (Fig. 2) and each phase consists of finding replies to specific questions of the process of analysis, design and implementation.

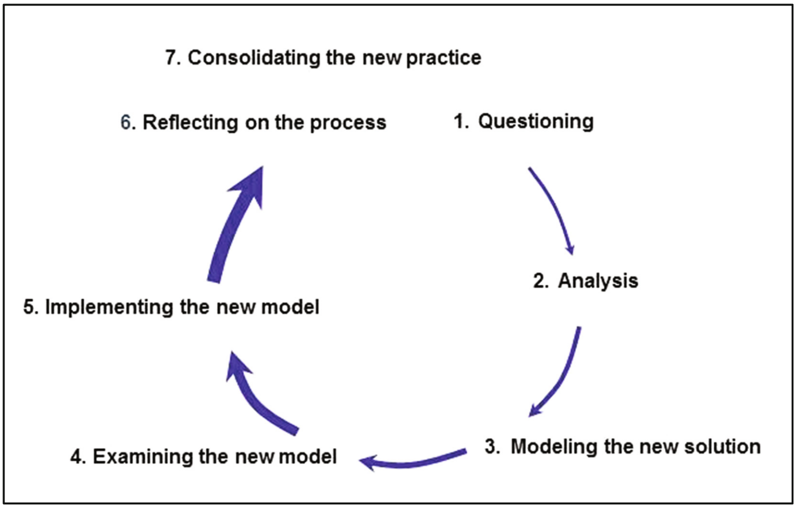

Fig. 2. Cycle of development to be followed in the CL sessions.

6 Data Collection

The visits to the field began in mid-2016. Thus far, 30 visits have been undertaken, with an average duration of 8 h each. In the final weeks it was possible to make more than one field visit a week, which made it possible to dedicate more time to observation for the collection of quantitative data, the holding of interviews, the analysis of documents, and observation.

The first visits were made to accompany the routine of the staff and the day-to-day relationship between the adolescents and the socio-educational support agents. To date, interviews have been undertaken with the staff. The interviews with the support agents were undertaken both in pairs and with individuals and there has been one session for the Collective Analysis of the Work – CAW[5] [20].

At the present time, conversation groups are being held with the internees to learn of the paths they followed before they were interned, what their daily life is like in the Center and their future prospects.

6.1 First Impressions of the Data Collected in the Interviews

In the workshops held with the staff it was possible to bring to light some problems experienced in the present organization of their work. Certain of the complaints are of a labor-law character and relate to e-mail messages received by the staff in the form of

[5] The Collective Analysis of Work (CAW) is a method which seeks to get to know the work activity on the basis of a group of workers who give details of the daily activity of their work so that the researcher may recognize the function without ever having observed the daily practice of the work.

directives which then become rules and generally arise from arbitrary decisions made without any preliminary consultation with the workers.

The absence of channels of communication with the management was collectively stated by the staff as something negative and which caused a certain feeling of revolt in some of the members of the team who did not understand the logic of some authoritarian decisions. This impacted the carrying out of the work, as in the case of the determination of work targets to be achieved, which were often at variance with the real conditions which the staff had to face.

The high rate of absenteeism is felt to be negative by both sides. Both the managers and the staff suffer from the weakening of the functioning staff, though the measures adopted by the managers to address the problem are not directed at the real causes of the high level of workers' absences. The managers opt for punishing the workers who stay away, reducing the value of the bonus they receive, or by retarding their professional promotion, measures which serve simply to feed the vicious circle: lack of work satisfaction – absence of the worker.

The situations of violence seem to be a subject more restricted to the relationship between the internees and the socio-educational support agents. Even though this problem has been minimized with the change in the local management, it is a disturbing circumstance and may occur again at any moment, unless measures are adopted to give new meaning to the internal relationships.

7 Research Hypotheses

There are countless academic studies which take as the theme of their research questions related to the CSAA Foundation and they are generally related to the fields of the social sciences, education and health. The surveys on health address the conditions of the adolescents who live in a total institution. Little has been observed with regard to the health of the socio-educational support agents.

Of the studies which investigate the health-work relationship, the research undertaken by the Regional Work Department in cooperation with Fundacentro[6], in 2008, which focused on the working conditions of the "monitors" (as the agents were then called) will be taken as our frame of reference.

The researchers were in the field in 2003, at the request of the trade union which represented the staff, to investigate the causes of the psycho-emotional sickness which was affecting the staff of FEBEM, as it was then called. The research concluded that many absences due to emotional disturbances were directly related to the frequent episodes of violence, leading many of the workers into the use and abuse of alcohol and drugs, depression, sexual impotence, stress, including post-traumatic stress due to situations of violence and physical aggression, the Burnout syndrome, as well as other related disturbances [14].

[6] Federal State entities responsible, respectively, for the inspection of labor norms and of the specific regulation of the themes of health and work safety.

In view of this, the investigation of the determining factors of the violent behavior occurring in the institution will assist in the search for solutions which minimize or even eliminate occurrences of this type. The historical review of the forms of violence experienced by both sides may reveal key contradictions in the system of the activity of the CSAA Foundation. How far did the change fail to consider the subject more carefully? Or, further, which practices survived over time, in such a way as to hinder the resignification of internal relationships? These are pertinent questions to be answered in the next stages of our investigation.

8 The Next Steps

The next step will be: to give continuity to the conversation groups with the adolescents. The conversations will be on given themes, and each meeting will address one of the questions: the most notable ones being work; sexuality; stress and sleep; family – work and social relationships, and the lack of prospects on leaving the institution; and it should then be possible to regard the Foundation with other eyes and suggest changes which consider it not only as a space for disputes with the staff.

A specific theme will be raised with the adolescents to get them to describe their experience of daily living in the Center to bring to light the contradictions and periods of tension in their daily experience.

Three interviews will be held for conversations with the top management. Two interviews will also be held with regional directors in the next stage. At the end of the conversations, the data will be systematized for the beginning of the sessions of the Change Laboratory foreseen to begin in May 2017.

References

1. Portal G1 (campinas e região): Tumulto na Fundação Casa termina com três feridos em Campinas, SP. http://g1.globo.com/sp/campinas-regiao/noticia/2015/10/tumulto-na-fundacao-casa-termina-com-tres-feridos-em-campinas-sp.html. Accessed 10 Nov 2015
2. Negretti, N.: Madá e Lena entrecruzadas, dois dramas em trama: entre percursos numa tragédia social e uma constituição possível. Dissertação (Mestrado em Ciências Sociais) – Pontifícia Universidade Católica de São Paulo (2015)
3. Organização Mundial da Saúde. Informe mundial sobre la violencia y salud. OMS, Genebra (SWZ) (2002)
4. A violência no Brasil. Entrevista com Sergio Adorno. 33′42″. Publicado em 12 de janeiro de 2017. https://www.youtube.com/watch?v=Gj2odAHhPA4&t=15s. Accessed Mar 2017
5. Seligmann-Silva, E.: Trabalho e desgaste mental: o direito de ser dono de si mesmo, 624 p. Cortez, São Paulo (2011)
6. Goffmann, E.: Manicômios, prisões e conventos. Perspectiva, São Paulo (1992)
7. Diuana, V., et al.: Saúde em prisões: representações e práticas dos agentes de segurança penitenciária no Rio de Janeiro, Brasil. Cad. Saúde Pública, vol. 24(8), pp. 1887–1896 (2008)
8. Beltramelli, S.N.: Direitos Humanos, 3 edn. Juspodivm, Salvador (2016)

9. Brasil. Sistema Nacional de Socioeducação - SINASE. Brasília: Presidência da República. Lei Federal nº 12.594 de 18 de janeiro de (2012)
10. Teixeira Souza, J.L.: A situação do encarceramento de jovens autores de ato infracionais em São Paulo. In: Souza, L.A.F., org. Políticas de segurança pública no estado de São Paulo: situações e perspectivas a partir das pesquisas do Observatório de Segurança Pública da UNESP, 219 p. Editora UNESP, São Paulo, Cultura Acadêmica, São Paulo (2009)
11. Corte Interamericana de Direitos Humanos. Resolução da Corte Interamericana de Direitos Humanos: Caso das crianças e adolescentes privados de liberdade no "Complexo do Tatuapé" da FEBEM. San Jose, Costa Rica (2005). http://www.corteidh.or.cr/docs/medidas/febem_se_01_portugues.pdf. Accessed 9 Mar 2017
12. Plano Político Pedagógico. CASA Campinas. Campinas (2016)
13. Brasil. Estatuto da Criança e do Adolescente. Lei Federal nº 8069 de 13 de julho de 1990. Imprensa oficial, São Paulo (2008)
14. Tavares, E.P.N., et al.: O trabalho dos monitores na Febem. FUNDACENTRO, São Paulo (2008)
15. Superintendência de Segurança e Disciplina. Conceitos, diretrizes e Procedimentos, São Paulo (2010)
16. Engestrom, Y.: Aprendizagem Expansiva. Pontes Editores, Campinas (2016)
17. Virkkunen, J., Newnham, D.S.: O laboratório de mudança: uma ferramenta de desenvolvimento colaborativo para o trabalho e a educação, 424 p. Belo Horizonte, Fabrefactum (2015)
18. Virkkunen, J., Vilela, R.A.G., Querol, M.A.P., Lopes, M.G.R.: O Laboratório de Mudança como ferramenta para transformação colaborativa de atividades de trabalho: uma entrevista com Jaakko Virkkunen, vol. 23(1), pp. 336–344. Saúde e Sociedade (USP. Impresso), São Paulo (2014)
19. Querol, M.A.P., Filho, J.M.J., Cassandre, M.P.: Change Laboratory: Uma proposta Metodológica para pesquisa e desenvolvimento da aprendizagem organizacional, vol. 12 (4), pp. 609–640. Administração: Ensino e Pesquisa, Rio de Janeiro, October/November/December 2011
20. Ferreira, L.L.: Análise coletiva do trabalho. Rev. Bras. Saúde Ocupacional **21**(78), 7–19 (1993). São Paulo

A Survey on Occupational Safety and Health Awareness Among School Teachers in Kelantan, Malaysia

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Abstract. Nowadays, more accident cases reported in school cause not only injuries, but also deaths. This indicates that the importance of safety and health measures in school should be exposed not only to students but most importantly to teachers who will be guiding and providing safety and health culture in school. This paper is based on the study that was motivated by the increasing reports of accidents in school. The objective of the study was to measure the understanding regarding safety and health among school teachers in Kelantan by distributing questionnaires consist of ten District Education Offices (PPD) in Kelantan, Malaysia. The results show that most of the respondents understand about safety and health matters with the importance of implementing safety and health in school. In conclusion, further study on workplace assessment need to be conducted at school to identify the implementation of safety and health among school community.

Keywords: Perception · School · Teachers · Safety · Health · Commitment · Environment

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1 Introduction

Recent years have witnessed increasing reports of accidents that occur in school area. The reported accidents have caused not only injuries but also deaths. This is a disturbing situation as parents normally feel that school is a safe place for their children to be in. Schools become one of the largest categories of the workplace because children, teachers and other members of staff spend a lot of their time in schools exposing them to a variety of risks and hazards through physical and social activities. This condition may negatively affect their wellbeing [1]. A previous study reported that students spend their 180 days in a year, 6 h daily in a school in Turkey [2]. According to Japan Sports Council, the largest set of school injury data in Japan, is approximately one million injuries occured in elementary, junior high and high schools each year and this remains relatively stable year by year [3]. In 2016, records of accidents in school that indicate the case of mercury spill in laboratories are high and mercury is one of the chemical hazards that harmful to human body. Meanwhile, there are also accidents occurs in school involving death; student hit by goalpost at the field, student fall into sewer and fall from a high building. However, school accidents causing injuries have not been investigated as widely as those occurring at home or in road traffic accidents [4]. This is due to the general belief that children are relatively protected in school because of the safe environment and supervision. School is considered a place of work. In the Occupational Safety and Health Act 1994 (Act 514) “place of work” means premises where person’s work or premises used for the storage of plant and substance [5]. In order to prevent danger situations occuring in schools, safety condition in school needs to be considered and improved in all of the aspects covering the school physical environment and the social environment [2].

A significant number of accidents can be traced to unsafe behaviours. Poorly designed equipment or operations, poor systems and poor working conditions can all encourage unsafe behaviours, but these behaviours are not inevitable. An organisation’s attitudes and values regarding safe working are important factors that influence its approach to work and safety performance. Put another way, it’s not enough to provide safe equipment, systems and procedures if the culture doesn’t encourage healthy and safe working environment. Safety culture has been defined as consisting of shared values (what is important) and beliefs (how things work) to produce behavioral standards which are interact with an organisations structure and control systems [6]. Safety culture can also be explained as a combination of how people feel about safety which is about the safety climate, what they actually do and the policies and procedures that organisation has implement in workpalce [7]. Apart from that, one way of identifying the need to improve an organsation’s health and safety culture is to evaluate the current safety climate. Safety climate surveys describe an organisation’s culture using some factors including how much employees understand and communicate about safety and health, how committed and responsible they are in order to maintain their own health and other people’s health [6].

Accidents rate in the industry can be reduced if students at the school are exposed to issues of occupational safety and health [8]. This means that teachers play an important role in exposing how safe students should believe and perceive while they were in the school surroundings [9]. Thus, in order to create a safer work environment, the school community needs to create a culture of safety in school. This suggests that the involvement of all parties is the foundation of development safety culture in school [10]. Support must be provided by all levels of management and employees [11]. Through a comprehensive environment, the concept of employee engagement is the process of worker solidarity, participation, and contribution in the process of improving safety and health [12].

Students, teachers and the management must stick together and must be committed to every programmes conducted to create more awareness of safety at work. A strong commitment from the management is very important in terms of safety and health, especially in providing basic occupational safety and health as well as in the implementation of those policies. The management must plan and carry out programs or related activities such as identifying hazards, provide safety committees, training of employees, conducting workplace inspections, investigate accidents, and supply of personal protective equipment. The implementation of these activities should be monitored, updated and improved on an ongoing basis assessment to ensure its effectiveness [13].

Apart from that, management is one of the important things that need to be taken seriously in every work. Commitment of the management is needed to ensure the safety of students is maintained while doing some activities in the school such as in workshops or laboratories. Safety environment will not be implemented without the cooperation of students and teachers themselves. Their role is to comply with all the regulations, the directives, and measures on health and safety management in school [14]. Besides that, the management of occupational safety and health cannot be viewed as insignificant and isolated from the total management of an organization [15].

Some studies stated that the safety culture of an organization is related to attitude, behaviour, system and environmental factors that were implemented by the organization for creating and maintaining effective safety and health management system [16]. Brad Dhal's studies found out that teacher's perception regarding school safety was affected by many of the same factors [9]. Those factors include commitment, personal characteristics, contextual characteristics, processes and environmental factors. In other studies, some of the teachers report that relationships and the learning atmosphere are key factors in making school's ground safe. It is possible that teachers who work in the same school have different perceptions towards the school safety due to the differences in their experiences, perspectives, ages or roles in their school's management structures [17].

Promoting safety in the workplace is a key component to every organization. The measurement of perception regarding safety among employees in their workplace is one method to gather information on this topic [18]. Information gathered from the corresponding organization will help in gaining a better understanding of employees' perceptions, as well as improving their ability to evaluate and maintain existing initiatives and design new programmes to implement a safer and a healthier environment in the workplace.

Thus, this paper examines the understanding of teachers regarding safety and health in school. It focuses on the behavioral perspective regarding commitment and awareness about the importance of safety culture in schools.

2 Research Methodology

This paper adopts a quantitative approach to assess the safety climate among school teachers in the state of Kelantan, Malaysia. Kelantan is a state located in the north east of peninsular Malaysia. It has a total number of 592 schools spreading all over ten District Education Offices (PPD). This paper presents the result and finding based on a questionnaire survey distributed among 1,000 school teachers from 100 schools randomly selected from the ten PPD.

The questionnaires aim to measure the levels of commitment and awareness toward/about the importance of safety and health environment/practices in school surroundings of the teachers. The questionnaire was divided into two parts. Section A is for demographic background of the respondents. Section B is for safety and health elements. Questions about safety and health elements focus on two main factors namely commitment towards promoting the safety culture, and awareness about safety and health environment/practices. Figure 1 exhibits the flow chart of this study.

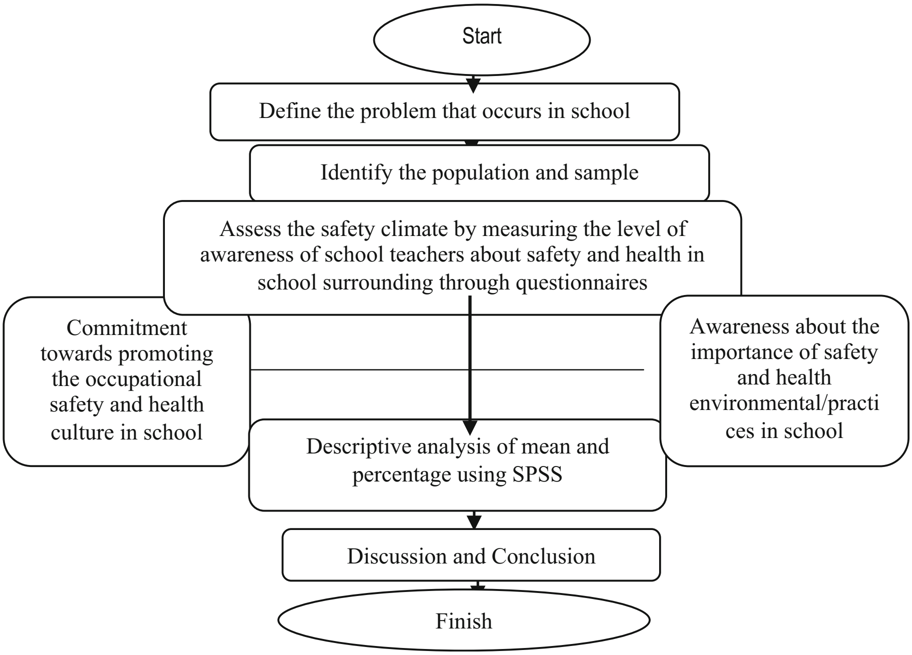

Fig. 1. A flow chart of this study

3 Results and Discussion

This section presents the result obtained from the questionnaire survey. The results were analyzed by using Statistical Package for the Social Sciences (SPSS). Figure 2 shows the percentage of respondents by gender. It shows that 35.6% are males and 64.3% are females.

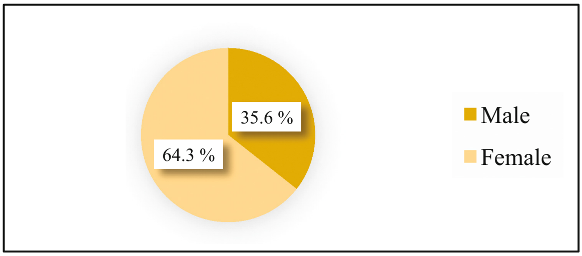

Fig. 2. Percentage of respondents by gender

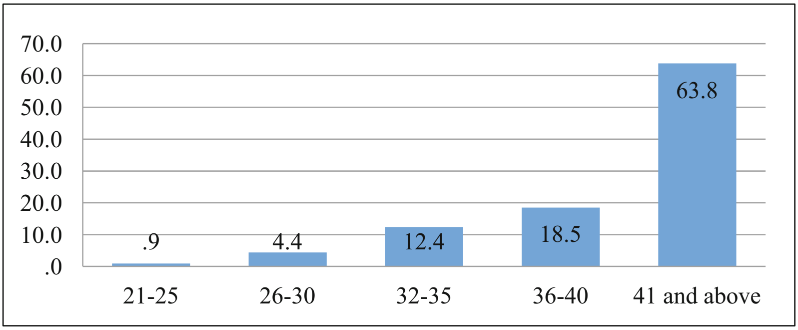

Fig. 3. Percentage of respondents by age

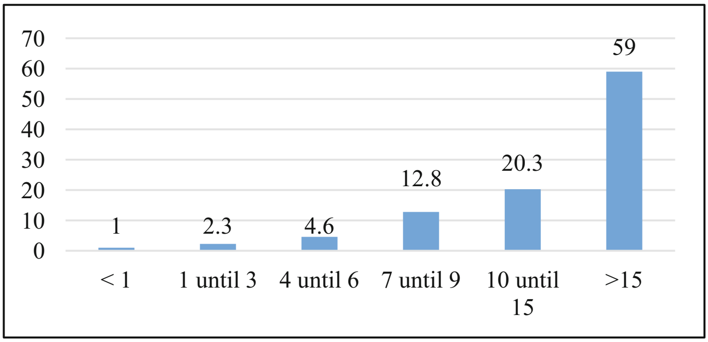

Fig. 4. Percentage respondents by working years

Figure 3 shows the percentage of respondent's age in school. The result shows that 63.8% are 41 years old and above, 18.5% are 36–40 years old, 12.4% are 32–35 years old and 9% are 21–25 years old.

Besides that, Fig. 4 shows the percentage of working period of the respondents. The result shows that 59% of them have been working for more than 15 years in school. Meanwhile 20.3% have been working as teachers for 10 to 15 years, 12.8% of them have been working for 7 to 9 years, 4.6% of the teachers have been working for 4 to 6 years. 2.3% of the teachers have been working for 1 to 3 years and only 1% of the teachers have been working for less than a year.

Figure 5 shows that academic background of teachers. Based on the result, 65.4% of teachers are from degree background, 19.5% have master, 8.2% have diploma, 4.9% have teaching certificate and 0.4% have degree.

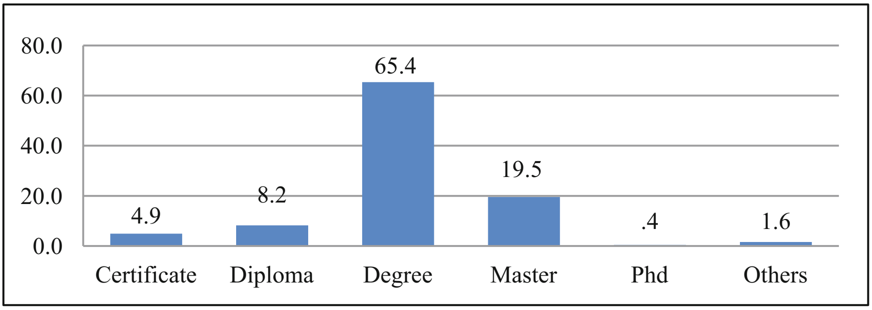

Fig. 5. Percentage of respondents by academic background

It summarizes that majority of the respondents are females (64.3%), aged between 41 and above years old (63.8%) with more than 15 years of working experience (59%), and with a bachelor's degree for academic background (65.4%). The knowledge or perceptions on safety and health among employees were influenced by the background of the persons in terms of age, gender, working period and academic background [19].

Table 1. Reliability statistics for commitment aspect

Cronbach's alpha	Cronbach's alpha based on standardized items	N of Items
.889	.894	11

Table 2. Reliability statistics for environmental aspect

Cronbach's alpha	Cronbach's alpha based on standardized items	N of items
.921	.923	10

Table 1 shows the reliability statistics for the commitment questions used in this study. The result shows that Cronbach's Alpha is 0.889 which is considered reliable for the data. Meanwhile, Table 2 shows the reliability statistics for Environmental Aspect questions which result 0.921 for Cronbach's Alpha. It also considered as reliable data.

Apart from that, Tables 3 and 4 show the item total statistics which measures the validity of each question. It shows that, the alpha value for total correlation is lower than Cronbach's Alpha If Item Deleted. This means the questions used in this study are valid and accepted [20].

Table 3. Item total statistics of commitment aspect question

Question	Corrected item-total correlation	Cronbach's alpha if item deleted
AQ1	0.589	0.881
AQ2	0.639	0.878
AQ3	0.665	0.877
AQ4	0.671	0.876
AQ5	0.616	0.881
AQ6	0.590	0.882
AQ7	0.605	0.880
AQ8	0.657	0.877
AQ9	0.462	0.888
AQ10	0.652	0.877
AQ11	0.653	0.877

Table 4. Item total statistics of environmental aspect question

Question	Corrected item-total correlation	Cronbach's alpha if item deleted
BQ1	0.608	0.919
BQ2	0.674	0.915
BQ3	0.700	0.913
BQ4	0.763	0.910
BQ5	0.764	0.910
BQ6	0.734	0.912
BQ7	0.644	0.917
BQ8	0.693	0.914
BQ9	0.741	0.911
BQ10	0.734	0.912

On the other hand, Table 5 shows the data of perception regarding the commitment aspect among the school teachers. Based on table below, the mean score for each question is between 4 and 5, indicating that the responses for the questions of the commitment aspect do not conflict each other.

The result also shows that most of the respondents are committed to implement safety and health in school. They aware about smoking are not appropriate attitude that shows in school. Besides that, based on the questions AQ6 and AQ9, it means that the teachers are aware that commitment is one of the safety and health elements are needed in an organization. Apart from that, the questions AQ7 and AQ8 means that they have agreed to give their commitment in order to make sure that the safety and health surroundings in school can comply with the Occupational Safety and Health Act 1994. Some researchers noted that organizational health and safety is more effective in many countries if they show good attitudes in the first place rather than focusing on the regulations and policies in the workplace [21]. This shows that there is a link between collective commitment to the health and safety criteria [22]. Apart from that, poor commitments among the management of the school will escalate a higher rate of unsafe working situations that can cause accidents [13].

Table 5. The mean scores for teachers' commitment towards safety and health

Questions	Items of Commitment	Mean	St. deviation
AQI	I do not smoke in prohibited places	4.661	.5821
AQ2	I should work carefully	4.6310	.5302
AQ3	Worker safety and health must be a priority	4.6060	.5613
AQ4	My negligence in maintaining safety and health will cause danger to ourselves, students and colleagues	4.5850	.5892
AQ5	Any damaged equipments are reported immediately	4.5540	.5616
AQ6	I will inform the students and colleagues about the importance of safety and health aspect	4.5195	.5745
AQ7	I always ensure that the equipments are clean and tidy after using them	4.4270	.6489
AQ8	I always follow the rules provided by the school	4.3680	.5924
AQ9	I will check the equipment to be used before doing the job	4.1822	.6661
AQ10	Personal protective equipment does not disturb me in doing my job	4.1131	.79087
AQ11	I like to use personal protective equipments when doing job	4.0981	.81469

Then, the environmental aspect is also one of the factors in helping to identify hazards and risks that occur in the school area. Table 6 shows the data of the teachers' perception regarding environmental aspect in school. From the result, school teachers are aware of the importance of creating a safer environment in their school due to an item in the question given. They agree about lighting in their workplace are sufficient and they feel comfort while teaching in class. The question "I always…" shows that teachers are always ensured that the workplace environment is in tidy and clean conditions. On the other hand, rubbish that are collected in school was disposed off in an appropriate place. Thus we could see that the school's management has already

Table 6. The mean scores for teachers' awareness about the existence of environmental aspect among teachers

Questions	Items of awareness	Mean	Std. deviation
BQ1	The lighting in my workplace are sufficient	4.3740	.61523
BQ2	Barricade should be made on the machines that are dangerous	4.3690	.68066
BQ3	I always keep the floor clean from oil, dust, water and materials that may cause unsafe condition	4.3670	.60719
BQ4	Air circulation system in good condition.	4.3520	.61030
BQ5	Working surrounding in school safe	4.3160	.61524
BQ6	Equipment are arrange in tidy and safe condition	4.3150	.61981
BQ7	I always ensure aisle not disturb by any obstacle	4.3110	.61860
BQ8	Equipment are keep in appropriate place, label and isolate according to harmful and not harmful substances	4.3050	.66364
BQ9	There are many exit signage provided in school	4.2880	.72082
BQ10	Waste are collect and keep in appropriate place	4.2420	.66624

practiced the safety and health aspects in their school. Knowledge regarding safety and health in the workplace is important to create a safer working and learning environment, the safety of handling technical equipment and the optimization of the working conditions in order to maintain a safer and healthier workplace. A safer environment can help employees feel safe [23, 24].

4 Conclusion

This paper has focused on the preliminary assessment of the safety climate in schools by using questionnaires survey. As a conclusion, the result suggests that teachers in the study area do have knowledge on a safety and health practice in school. Further studies about safety and health culture may consider the theory of behaviour as well as Safety Culture Maturity Model by the Keil Centre. Focus can also be put on measuring the effectiveness of safety and health implementation in the schools. It is hoped that the number of accidents in school (including the loss of property whether directly or indirectly) also can be reduced with the commitment of school management. This is because collaboration between school management and teachers is an important factor to ensure an effective implementation of safety and health culture in school.

References

1. Anna, D.: Safety management in Catalonia's school. Soc. Behav. Sci. **46**, 3324–3328 (2012)
2. Erkan, T., Bektaş, T.: Student safety in primary schools: a sample of Buyukcekmece county. Procedia Soc. Behav. Sci. **1**, 281–284 (2009)

3. Japan, S.C.: Report of the accidents in schools (2002). http://www.jpnsport.go.jp/anzen/Portals/0/anzen/kenko/jyouhou/pdf/H26saigai/H26saigai8_3.pdf
4. Scheps, S.B., Dewey Evans, G.: Epidemiology of school injuries: a 2-year experience in a municipal health department. Pediatrics **79**, 69–75 (1987)
5. NSKC: Promoting Child Safety to Prevent Unintentional Injury. School Injury Fact Sheet, Washington DC (2004). http://www.safekids.org
6. www.iosh.co.uk/freeguides (2015). Promoting a positive culture A guide to health and safety culture. file:///D:/UMK/Downloads/Promoting%20a%20positive%20culture.pdf
7. Cooper, M.D.: Towards a model safety culture. Saf. Sci. **36**, 111–136 (2000)
8. Fong, C.: Teks Ucapan Pelancaran Kempen Bulan Keselamatan dan Kesihatan Pekerjaan. Kementerian Sumber Manusia, Kuala Lumpur (2000)
9. Brad, D.: Perceptions of school safety. In: EDAD 9550 Symposium on School Leadership, University of Nebraska at Omaha, 26 June 2012
10. Misnan, M.S.: Modul Pembangunan Budaya Keselamatan Dalam Firma Pembinaan di Malaysia. Ph.D. Tesis, Universiti Teknologi Malaysia (2009)
11. Page, S.: Worker Participation in Health & Safety Representation. Health and safety executive, London (2002)
12. Goetsch, D.: Occupational Safety and Health for Technologies, Engineers and Managers, 7th edn. Pearson Prentice Hill, New Jersey (2011)
13. Ismail, W.: Kesedaran Keselamatan dalam Kalangan Pelajar Kolej Kemahiran Tinggi Mara di Lembah Kelang. Fakulti Kejuruteraan Teknikal dan Vokasional, Universiti Tun Hussein Onn Malaysia (2012)
14. Dessler, G.: How to earn your employees' commitment. Acad. Manage. Executive **13**(2), 58–67 (1999)
15. Bahari, I.: Pengurusan Keselamatan dan Kesihatan Pekerjaan, Edisi Kedua. Bangi: Universiti Kebangsaan. Mc Graw Hill, Malaysia (2006)
16. Misnan, M.M.: Pembangunan Budaya Keselamatan di Tempat Kerja. Universiti Teknologi Malaysia, Johor Bharu (2011)
17. Booren, L.H.: Examining perceptions of school safety strategies, school climate and violence. Youth Violence Juvenile Justice **9**(2), 171–187 (2011)
18. Yukon, B.: Workpalce Safety: Perceptions of DSafety in the Workplace-Results from a Survey of Working People (2003)
19. Latif, A.: Primary school accident reporting in one education. Arch. Dis. Child. **2002**, 91–94 (2015)
20. Mohd, Y.: Analisis Data Penyelidikan Untuk Pendidikan (Pendidikan & Sains Sosial). Bandar Ilmu, Kuantan (2010)
21. Denis, S.M.: Building safer secondary schools in uganda through collective commitment to health and safety compliance. Int. J. Educ. Policy Res. Rev. **1**(4), 047–053 (2014)
22. Richardson, B., Curwen, P.: Do free-market governments create Crisis-Ridden societies? J. Bus. Ethics **14**, 551–560 (1995)
23. Kozik, T.: Výchova a vzdelávanie k BOZP z pohľadu celoživotného vzdelávanie v SR. In: Problemy profesjologii pólrocznik. ISSN 1895-197X (2013)
24. Melania, F.: Education for future teachers to OHS principles- safety in chemical laboratory. Procedia Soc. Behav. Sci. **191**, 890–895 (2015)

Human Aspects of Change Management and Implementation

Dynamics of Interactions – Motivation

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Abstract. The article discusses a model of response dynamics to arousal. The description of the dynamics may be used to dynamically interpret the first law of Yerkes-Dodson. The discussion has been founded on research into change implementation methods and concludes with a suggestion of a unique methodology of change implementation based on dynamical properties of an organization. As a result of the performed analyses, it has been found that the level of enthusiasm in completing a task delegated to an individual worker or a group of workers is correlated to the rate at which the tasks were completed and the distance to the goal completion. The correlation appears to validate the use of the first law of Yerkes-Dodson in the area of worker motivation and additionally offers insight into the issue of recognizing dynamical reasons for irrational behavior of crowds, the phenomenon of neophyte enthusiasm, and several other reactions.

Keywords: Dynamics of interaction · Yerkes-Dodson law · Motivation

1 Introduction

Motivation may be perceived as a process of self-regulation whose purpose is to control actions in order that a desired outcome is reached [1]. Such an interpretation implies a necessity of a wider explanation of various aspects of motivation in change implementation process. The concept of motivation plays a pivotal role for dynamics of influence exertion and as such requires a presentation of basic terminology. The concept itself appears to have earned such numerous definitions and descriptions that there has occurred some ambivalence in the way they are used.

Motivation has been explained as a process of psychological regulation determining where man's actions are aimed and how much energy expenditure is allocated for reaching the goal [2]. The motivation process is inherently linked to the concept of motivational tension. The tension is alleviated because of its gratification value. According to Reykowski, motivational tension follows a realization on the part of a subject that a state of affairs exists which has the potential of lessening the tension coupled with the perception that the state is achievable [3].

Theories of motivation draw among others from the body of knowledge about psychology of instincts, personality and learning [2]. Their connection to motivation is

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descriptive in nature. Instinct may be defined as “the capability of rational action without the capability of reasoning”. Motivation is, however, accompanied by the sense of agency. The agency is understood as an actor’s ability to initiate an act and choose which course of action to take. The acting subject feels responsible for the action and accepts responsibility for it. The actor could be a goal setting decision maker or a worker spontaneously deciding to initiate an action or planning to take an action in response to stimulating environmental conditions (e.g. incentive). This is how the process of multistage motivation with increasing impact unfolds. The decision-maker assumes the role of an animator who facilitates action by pointing to goals, benefits and potential consequences, whereas the decision to act and which course of action to follow is taken by the actor. The efficiency and effectiveness of the action depend on the impact of motivational process but it has to be borne in mind that there are limits to its influence. The effectiveness of a worker’s activity does not rely solely on the intensity of motivation processes but also on psychosocial conditions determining the worker’s mode of functioning in the environment.

Motivation theories include fundamental systems based on mechanisms triggering and sustaining actions [4].

2 Behavioral Mechanisms of Motivation

Behavioral perception of personality points to a direct correlation between a response (action) of a human to the corresponding arousal (stimulus). An identical model is applied to the analysis of responses of man viewed as a reactive being. Skorny [5] postulates that it may become a basis of behavior control applied by adequately manipulating stimuli and facilitated by knowledge of relationships holding between stimuli and projected responses. He adds that behavioral model is especially useful in analyzing animal behavior as well as simple acts[1] performed by man. The behavioral approach constitutes a form of cybernetic model of man according to Wiener [7], Mazur [8, 9] and other models of behavior derived from cybernetics [10–23].

Performing acts and tasks emergent from the assumed role is a consequence of changes occurring in the environment. Those changes result from the undertaken action. Acts in turn are conditioned by contexts in which they are to be performed [24]. The determination of acts and their effectiveness by contexts may be explained by the phenomenon of feedback meaning that an action[2] leads to a change of context in which it is taking place, and the context determines the course of the action itself [5].
Skorny lists the following categories of contexts [5]:

- short-term and long-term – typically short-term contexts determine long-term ones;
- favorable and unfavorable – resultant from a configuration of conditions securing success in task achievement;

[1] Act – “process directed at obtaining a result in a structure corresponding to conditions so that the possibility of obtaining the result is kept” [5, 6].

[2] Action – is determined by long-term goals. Action comprises acts, which are determined by short-term goals [5].

– spontaneous and deliberate – these latter are especially valuable from the perspective of studies on dynamics of change implementation since a planned change applied in a system is always deliberate in its context, let alone identification experiment which is carried out in given objects of organization;
– optimal – fully conducive to achievement of tasks, satisfaction of needs and to attainment of another specified (target) level of task achievement;
– normal – there occur identifiable possibilities of successful and effective achievement of the task but at the cost of additional effort;
– difficult – there exist serious obstacles to realizing the set goals to the extent the successful completion of the process is jeopardized.

Man does not function in the environment as an involuntary tool but displays conscious activity manifesting itself in the ability to transform the nature of the environment – be it directly or through intermediate actions performed as part of deliberate plans. In the process, evident is the significance of innovation understood as applying changes to the context of acts performed by an individual. Hence, it should be noted that such a formulation of imperative to act runs counter [25] to the behavioral concept of man regarded as a reactive (controllable) being.

This seeming contradiction is not factual as is evident in the behavior of a worker given a task to do and equipped with an instruction of how to do it. One of the most important features of an act (and thus an action) is a goal. A man who is performing an act is aware of its goal, the level of its attainment as well as the effectiveness of the performance in time. Consequently, acts are targeted and performed in a conscious manner. The existence of those aims causes a change in the intensity of stimuli affecting the man in the process of the aims' achievement. Stimuli frequently function not only as triggers to initiate actions but also as motivators. The actual performing of actions aimed at achieving specific goals may hence lead to a change in intensity of motivators[3]. The case in point would be a situation in which a worker has been given a goal to attain, is working towards reaching the goal and is at the same time aware that the distance to achieving the goal is decreasing as a result of the acts being performed. The primary goal which triggered an activity (the distance to goal) is modified automatically in the task completion process and plays a role of a variable intensity motivator. Its intensity decreases over time, it does not, however, always mean a drop in effectiveness of actions. According to the first law of Yerkes-Dodson (1YD) the efficiency of action is the highest with medium level of intensity of motivation and the lowest both when motivation is weak or too strong. It means that the correlation of efficiency of actions to the change of the action triggering stimulus is not monotonic.

An analysis of all forms of human activity demands investigating their dependence on the process of stimulation towards acting. This dependence of acting on motives appears to prove a claim that man is not controlled merely by external stimuli and contexts. Man consciously modifies interactions with environment and effects changes in the environment.

[3] The function of motivators may be performed by: emotions, needs, interests, aspirations, attitudes, norms of conduct [5].

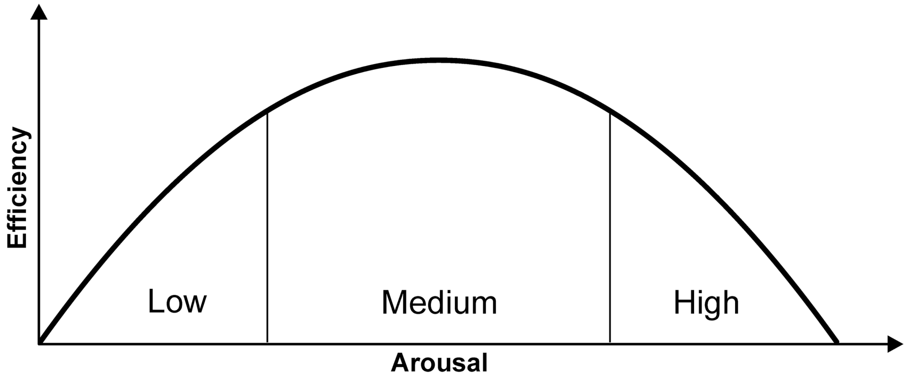

Fig. 1. The first law of Yerkes-Dodson [5]

It could thus be concluded that a worker who has been given instructions on how to execute a task is treated in accordance to behavioral concepts. The worker's conduct may be described within these theories as a response to certain requests. Conversely, due to volatility of context in which the acts are to be performed and which results from the worker's activity, initiative and intelligence as manifested in selecting various action strategies, it could be argued that the worker does not act as an unwitting reactive subject.

A useful approximation at a model of behavior would need to combine basic features of both the discussed concepts: man undertakes acts in response to stimuli but the manner of acting as well as the dynamics of response to the stimuli depend not only on personality traits (behaviorism) but also on the amassed emotions, aspirations, needs as well as the external context emergent from the performed activities and acts. It also seems that the model of acting may to a large extent be based on the role of action motivators. Their volatility during the execution of act will directly affect the dynamics of goal achievement. Such a concept may constitute a basis for a rule that could be used to determine the success of goal attainment in relation to the distance to the goal [26].

3 Motivation Process Dynamics in Change Implementation

Frequently a representation of a fragment of reality (system, arrangement, team) is a specific dynamic element. The use of dynamic elements in the description of management systems is possible because of the possibility of finding phenomenological imitation. If, for instance, during an analysis of a group response to an imposed request in the form of a new quality standard, the individuals in the group will be treated as discrete elements, a simulation of group behavior will be easier. With such an approach, obviously, necessary is a thorough knowledge of dynamics of individual persons (elements). At times, however, there exist no simple ways of linking phenomena determining dynamic features of an arrangement with their counterparts in physical sense.

A useful concept for the description of interaction and motivation is inertial second-order element which is similar to inertial first-order element but has extra inertia.

It is manifested in the fact that in the preliminary stage of a element's response to request, there occurs a zone of insensitivity. It does not mean there is lack of response but rather a "lazy initiation". There is a response evidenced by increased effect, it is, however, slower in its preliminary stages than for example during the inertial first-order element [26]. The subsequent action course is similar to the first-order element. Also here, there occurs an asymptotic convergence to target value determined by the level of step request; so it is a general form of response to request in which the motivation is conversely proportional to a stimulus. This in turn is a difference between: aim–effect.

Practical implementations are similar to inertial first-order element. It should actually be stated that the second-order element is a generalized version of the first-order element. Based on the examples given above one could point to a zone of slow response at the initial stages of activity, which could account for the increased inertia level.

There exists a certain class of contexts, which due to their specification bear striking resemblance to the characteristics of inertial second-order element. These are contexts in which there occurs request of unfamiliar nature and a worker (group) displays a low initial effectiveness of task completion. Among examples of such contexts are:

– execution of tasks within project management – such actions are temporary in nature (strictly defined timescale) with a specifically defined type and scope of resources (assets, information, personnel), and atypical (not in terms of technology, but conditions and specificity); the initiation of actions is cautious, which is manifested in the low initial performance levels, then there follows an acceleration in execution rate and improvement of effectiveness of actions (performance of actions within well-trained technologies), after which there occurs a decline of effectiveness resulting from a diminished impact of primary stimulus which is defined as the tension between target state and the current outcome of actions with resources nearing depletion.
– attainment of individual production by a group of workers – conditions similar to implementation within project management, despite lack of such management methods' standardization; similarly, initially there takes place a phase of recognizing the required scope of work and appreciating the degree of execution complexity, and a stage of selection of execution method, then there is a phase of highly effective goal-aimed effort, which is finally followed by a stage of low effectiveness.
– delegating a new task – exclusively if a worker is confronted with a new problem and has to come up with a method of accomplishing the task or learn to execute it in accordance with received instructions;
– delegating a task without specifying a provisional timeframe – if the worker is not given any deadline when specifying the task, adequate action may fail to be undertaken at the initial stages of task execution; the deadline is established only later (based on the received request or an analysis of previous tasks and accumulated experience); further course is coincident with the dynamics of inertial first-order element;
– aquiring a new skill by a worker or a team – this has also served as an example for inertial first-order element, as due to the specificity of context there may occur an instant, enthusiastic commencement of learning and training (inertial first-order) or

there is an apparent degree of “lag” typically caused by the necessity of familiarizing oneself with a more demanding task (inertial second-order).

The cases listed above display some common characteristics:

1. there is evident a low rate of goal attainment in the initial stages of task completion effort;
2. the rate is low also near the end of the cycle;
3. between the two stages the level of effort is the highest.

Considering the above and the fact that the discrepancy between the target state and the current level of completion plays a primary role in motivation, it could be concluded that:

– the rate of actions was lowest at the beginning of the process, when the difference between the target state and the achieved level is biggest (strongest motivation to achieve the goal),
– the rate of result accomplishment was equally low near the end of the change implementation process, when the distance” to goal was decreasing (lowest level of motivation),
– the rate of effort was highest for some intermediary level of motivation.

Figure 2 presents an example chart of the effect achieved in the function of time for an object with inertial second-order element characteristics and the chart of the first derivative of the curve. The derivative represents the pace (rate) of goal attainment – the steeper the slope of the goal attainment curve, the higher the rate, which translates into quicker and more effective actions in the function of time. Zone A in the figure is

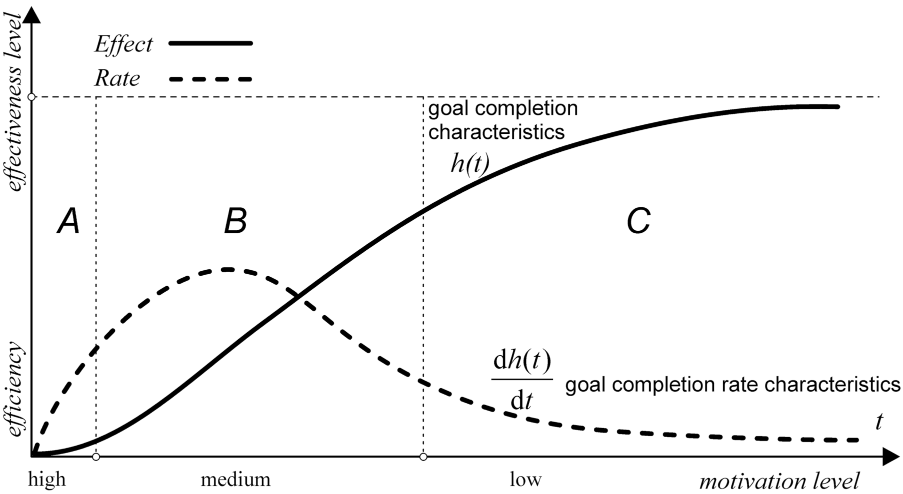

Fig. 2. Task completion by an object with inertial second-order element type dynamical characteristics: A – strong motivation zone, B – medium motivation zone, C – poor motivation zone [26].

the band of very high motivation, zone B corresponds to a medium level, whereas zone C is an area of very low motivation to act.

The curve representing the rate of goal attainment is reminiscent of a graph illustrating the first law of Yerkes-Dodson (Fig. 1). Both illustrate the same correlation: the highest rate of effort occurs at a certain optimal level of motivation which corresponds to the distance to the set goal. A very low as well as very high degree of motivation results in decreased efficiency and compromised effectiveness of actions, which proves the validity of regarding the dynamics of response to request also for inertial first-order element as a simplified variant of inertial second-order element.

4 Conclusions

The above considerations prove also that inertial first-order element in psychosocial contexts is a special case of inertial second-order element. It should be noted that cases with identified dynamical features characteristic of inertial first-order element concern contexts in which there occurred an instantaneous initiation of activity in response to exposure to request. Not only was there no delay but the rate of effect increase was highest in the initial stages of the cycle. This does not contradict the first law of Yerkes-Dodson (1YD) but rather seems to confirm it. There appears to occur a specific situation here in which there is no phase of familiarizing oneself with a new context or environment but one undertakes action as soon as possible and at the maximum level of effectiveness. This is possible in one case only. The task to be completed entails actions which are familiar, well-trained, and can performed efficiently and effectively. The task completion involves setting in motion a number of well-trained execution procedures. No phase of adaptation to new conditions is needed, nor is it necessary to learn a new craft, to practice cooperation within a new team or to assimilate to novel social or technological contexts. Consequently, there exists no strong fear of committing major mistakes since the execution of the new task relies on carrying out routine actions and subtasks.

According to 1YD, low effectiveness of task completion accompanied by high motivation level emerges from excess pressure which is conducive to occurrence of action blocking mechanisms as well as prevents one from taking decisions for fear of error. Very strong motivation stifles effective performance as it leads to repeated reviewing of the performed work or overzealous preparation for the task execution suggestive of fear of mistakes and errors. The overall effect is that of prolonged execution of procedures, repetition of activities and general impotence. Typically, these mechanisms will disappear with the accrued experience and know-how. Activities become ingrained through the process of adapting to new conditions and when these have become familiar the effect of strong motivation gives way to medium level motivation and the effectiveness of task completion considerably increases. It could be remarked that the resultant arrangement assumes the characteristics of inertial first-order element and that it indeed is responsible for execution of tasks in which the actor feels sufficiently confident to apply familiar and well-trained procedures, actions, tools, and rules.

Management and ergonomics are nondeterministic sciences in that formal models will never hold true for each real-life case and based on them it will not always be possible to accurately determine quantitative relationships characterizing a given phenomenon at a given time (provided adequate information on preliminary conditions is available). Nevertheless, numerous research results seem to confirm the validity of a thesis stating that there exists a degree of typicality of relationships among characteristic parameters in the studied organizational systems. This is the role of formal models: they allow recognition and prediction of trends or quantitative correlations in objects which do not yield to descriptions other than statistical.

References

1. Maslyk-Musial, E.: Strategic Management of Human Resources. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa (2000)
2. Dyrda, M.J.: Sociology and Social Psychology in Managing Organizations. Wydawnictwo Naukowe Medium, Warszawa (2004)
3. Reykowski, J.: Emotions and motivation. In: Tomaszewski, T. (ed.) Psychologia. PWN, Warszawa (1985)
4. Straker, D.: Changing Minds: in Detail. Syque Press, Crowthorne (2008)
5. Skorny, Z.: Regulatory Mechanisms of Human Actions. PWN, Warszawa (1989)
6. Tomaszewski, T.: Introduction to Psychology. PWN, Warszawa (1971)
7. Wiener, N.: Cybernetics – Control and Communication in an Animal and a Machine. PWN, Warszawa (1971)
8. Mazur, M.: Cybernetic Theory of Independent systems. PWN, Warszawa (1966)
9. Mazur, M.: Cybernetics and Character. Panstwowy Instytut Wydawniczy, Warszawa (1976)
10. Mindell, D.A.: Between Human and Machine: Feedback, Control, and Computing Before Cybernetics. Johns Hopkins University Press (2002)
11. Geyer, F., van der Zouwen, J. (eds.): Sociocybernetics: Complexity, Autopoiesis, and Observation of Social Systems. Greenwood Press (2001)
12. Sienkiewicz, P.: The search for Golem. On cybernetics and cyberneticists. Krajowa Agencja Wydawnicza, Warszawa (1988)
13. Biriukow, B.W., Geller, J.S.: Cybernetics in humanities. Zaklad Narodowy im. Ossolinskich, Wroclaw (1983)
14. Szostak, W.: Social Cybernetics. Uniwersytet Jagiellonski. Instytut Nauk Politycznych, Krakow (1978)
15. Kossecki, J.: Social Cybernetics. PWN, Warszawa (1975)
16. Goscinski, J.W.: Elements of Cybernetics in Management. PWN, Warszawa (1968)
17. Saparina, J.: Human Cybernetics. Iskry, Warszawa (1966)
18. Tiuchtin, W.S.: Psyche and Cybernetics. Psychic Reflection in the Light of Cybernetics. Ksiazka i Wiedza, Warszawa (1966)
19. Cadwallader, M.L.: The cybernetic analysis of change in complex social organizations. Am. J. Sociol. **65**(2), 154–157 (1959)
20. von Bertalanffy, L.: General Theory of Systems. PWN, Warszawa (1984)
21. Carver, C.S.: A cybernetic model of self–attention processes. J. Pers. Soc. Psychol. **37**(8), 1251–1281 (1979)
22. Carver, C.S, Scheier M.F.: Control theory: a useful conceptual framework for personality–social, clinical, and health psychology. The Self in Social Psychology, pp. 299–316 (1999)

23. Carver, C.S., Scheier M.F.: On the Self–Regulation of Behavior. Cambridge University Press (2001)
24. Festinger, L.: A Theory of Cognitive Dissonanse. Stanford University Press, Evanston (1957)
25. Powers, W.T.: Feedback: Beyond behaviorism. Science **179**, 351–356 (1973)
26. Wisniewski, Z.: Organizational change implementation. Dynamic Approach. Wydawnictwo Politechniki Lodzkiej, Lodz (2010)

A Change of Approach to Management from the Functional to the Process One – A Human Factor and an Administrative Factor in a Public University

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Abstract. This paper is an attempt to define the factors which determine a transition from a functional approach to the process one in public higher education institutions. The determination of which factor, the human one or the administrative one, define the aims of the changes of management style and the choice of the methods of these changes were the interesting aspects of the conducted research. To evaluate the organization's process maturity, we took into consideration the most important elements of the process approach and the specificity of the activities of public higher education institutions, including: an approach to a creation of organizational structure, an internal capacity to delegate tasks and a capacity to identify the value chain. The deliberations were based on the research conducted in public higher education institutions and on the detailed analysis of one of the biggest universities in Poland.

Keywords: Process maturity · Process management

1 Introduction

Higher education institutions are important employers, often the biggest ones in the cities or regions, with enormous operational and investment budgets. At the same time they are managed by academic teachers who, in the majority of cases, do not possess sufficient knowledge from the field of management and have limited possibilities of benefiting from the experience of professionals in this area of knowledge [1].

There is a close link between a process maturity and the results which are obtained by a given organization [2]. In the literature one can come across even very sophisticated models of the evaluation of maturity but an application of a typical model for the evaluation of maturity for a given specificity is connected with a big threat that it might be inadequate for the character of activities of a public higher education institution [3, 4]. It is also not certain whether a structure of the parameters describing the maturity is correctly adjusted to the aim of evaluation in the given circumstances [5]. It cannot be assumed a priori that a model of the evaluation of the company's maturity universal for a given group will be the right one in all the conditions of its operations and that it will be the correct one taking the aim of the evaluation into consideration [6].

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In order to define the way of changing the management style into the process one it is first of all necessary to define where the needs of such changes derive from. There are two potential reasons: external and internal ones. The internal one can be associated with employees and their needs and the external one is imposed on the staff by the managers. The research tried to identify the reason for changes in higher education institutions.

The presented deliberations were based on the research conducted in public higher education institutions and the detailed analysis of one of the biggest universities in Poland.

2 Research Method

In case of the public higher education institutions a way of the evaluation of the process maturity taking into consideration the most important elements of the process approach and the specificity of the activities of the public universities was applied. These universities do not follow easily the evaluation of the process maturity [7]. The identified need to apply a process approach does not always lead to an improvement of activities.

Among the elements of the process management which must be examined in case of a public higher education institution the following ones must be mentioned: an approach to building an organizational structure, an internal capacity to delegate tasks and a capacity to identify a chain of the creation of values and its management [8]. These are the descriptors which are so significant for the process approach that they should be used as the distinguishing features of the application of this method of management [9] and on the other hand are a group of features which generally can be used to assess a level of management of a public higher education institution. In order to make this evaluation a correct one, a set of descriptors must be complete and separable. The usage of the indicated three dimensions of the evaluation allows to define a level of process approach of the analyzed organization and to define the range of impact of certain aspects on the process management within the organization.

The occurrence of a certain value in one of the dimensions (descriptors) does not determine the appearance of a certain value in a different dimension. This means their divisibility. During the research in public higher education institutions it was defined that the listed three dimensions are sufficient and they are often the only features from the field of the process approach which can be mentioned in case of a public higher education institution. In this approach they are a total description.

3 Results of Analysis

3.1 Approach to Building an Organizational Structure

An internal formalization is connected with the functioning of a given organization [10]. The structure of the organization is a combination of the defined functional and hierarchical dependencies between the elements grouped into departments and organizational units in the way which allows to achieve the aims of the whole organizations [11].

The analyzed higher education institution which is a case study is the university with more than 70 years of the academic tradition. It is a public technical university. The following elements exert influence on the organizational structure: a way of managing it, the principle of term limits, internal division of forces and different areas of influence.

The strategy transformed into a group of processes which serve to implement it should be a determinant of the organizational structure. In the majority of the public higher education institutions the structure is an invariant of transformation. However, it should be functionally dependent on the strategy and directly on the structure of the processes resulting from it.

In practice it turns out that an archaic structure of a university deriving from an old academic tradition is an obstacle to achieve the defined aims.

The first step to achieve a client-oriented and quality- oriented approach is an attempt done by the authorities of the university to look at the organizational structure not as on a static and a petrified element but in a flexible and process way. The level of the adequacy of the structure to a strategy indirectly shows a capacity for process actions [12]. The flexibility in the modification of the structure and a readiness for a quick reconfiguration is a next aspect which defines a maturity of the organization in the process approach within a structure [13]. In the analyzed higher education institution no symptoms of determining the structure of the system by the strategy were found. Additionally such a link is considered by the majority of the universities as redundant.

3.2 Capacity to Delegate Tasks and Responsibilities with Appropriate Permissions

The managers are attached to a functional approach in which the employees divided into proper organizational units are treated only as the executors of the defined tasks. This dissonance becomes bigger because in the public higher education institutions the organizational structures have a tendency to create the so-called "silos"- the administrative units supervised by a given vice-rector. In such a case, an information flow, a definition of tasks which must be done between the different units and a definition of a person who is in charge of these tasks is blurred and becomes almost impossible. A permanent strengthening of the role of a functional approach to the management of the higher education institutions make the employees believe that they are only accounted for work which is done and not for the results which are defined for them. As the research showed, this causes the frustrations among the employees, a discouragement to engage in the development of the organization and in some aspects leads to a desire to create such a situation which will give them an opportunity to influence a created value of the service.

3.3 A Capacity of Organizations to Manage a Chain of the Creation of Values

The chain of the creation of values in the functioning of the higher education institution is the last of the analyzed elements. The identification of the chain of creating values is a very simple determinant of the process management. Without defining the mutual dependencies between the elements of the management system, the workflows, the definition of the relations of an internal client and an internal supplier, it is not possible to speak about the existence of the process approach. In the higher education institution which was examined it was impossible to identify any cycle of workflow in which certain executors would identify their role in increasing the value of the flow for a final client. On the contrary- certain executors know their tasks which must be done but are not able to refer them neither to strategic aims nor to their suppliers, internal clients or final client. Simultaneously the employees point at a need to influence the working environment, methods of work, an environment, a configuration of processes and so on. In such cases they define the resources necessary to execute the tasks and they manage the given material, human and financial resources in order to fulfill aims in optimal ways.

The majority of public higher education institutions shows a functional approach to management but understands the limitations resulting from such an approach. The management organs of universities noticed in the process approach a possibility for the development of the organization and that is why they decided to apply a solution which can increase the chances of an effective functioning.

The implementation of the rules of the process approach in universities turned out to be a real challenge due to a pilling of obstacles, mainly of human nature. According to the rules of the process approach in the analyzed higher education institution four groups of processes were distinguished: the processes of management, the main processes, auxiliary processes and service processes [14].

The university was so much used to the functional approach that the first iteration of the map of processes within it was only an apparent mapping of the existing processes, being more a reflection of the functional structure in the form of the scheme of the "actions which are taking place".

In case of the analyzed university, the structure of processes which was obtained was only a reflection of the organizational scheme and had little in common with the workflows which are done and the range of responsibilities. The evaluation of the map of processes of the institution, which was preceded by the change of the mentality of people used to a functional approach responsible for the implementation and by a critical opinion of analytics "from outside", was a transformation of the map of processes in the "functional" approach into a map of a process approach.

The horizontal links and the dependencies of activities in the different, organizationally distinguished activities within the organization derive from the new system of processes. Thanks to the map, within the university people began to be aware of the existing links and of analogical processes in the areas with the different organizational subordination.

That is why already in the moment of choosing the owners- i.e. people responsible for the processes- there are conflicts as according to the current functional approach every person with a function considers themselves to the best leader of the process. However, the essence of the process approach is based on the engagement in the implementation of managerial functions of the owners of processes who know the most about them and who have a real causative role on the entrusted resources. In reality, these are not always people who have managerial functions within a given organizational unit. In such cases one deals with a situation that an administrative factor as an imperative of changes towards a process approach fails. The human factor is therefore dominating which enforces not only a transition to a process approach but also taking the ownership of processes by people who are the most interested in the role in the chain of the creation of values.

4 Summary

In the analyzed higher education institution a transfer to process management is a revolutionary activity. A look at the university by the prism of the processes shows that such an approach does not go side by side with the functioning organizational structure. The process management in the framework of the current organizational structure is questioned because in the distinguished processes there are the activities done by the different organizational units subordinated to the different departments and the different areas of administration.

The overcoming of a long, multi-level organizational structure and a definition of a real responsibility for processes constitute the difficulties in obtaining an effectively performing process [15]. The activity of employees is not concentrated on searching the effective ways of the implementation of processes because the decision-making powers are related to a formal position in the hierarchy [16].

The lack of the proper owner supervision in the public higher education institutions causes the fact that the development strategies are of a low quality, if of course they are created [17]. The good exceptions result from the ardor of enthusiasts and not from the systemic solutions. It proves that also here the human factor and not the administrative one dominates. If the employees understand a need to make a good strategy, a good solution is created. In the majority of cases the strategies are prepared because higher education institutions are obliged to prepare them by the legal provisions [18]. Such strategies have a low quality.

In the analyzed university, the mapping of the processes was perceived as a chance to increase the role of the document of strategy. The connection of the strategic aims and operational activities with single processes provides a system of mutually beneficial relations where every process should implement the aims defined in the university strategy [19, 20]. In this way the strategy is translated into specific aims and actions.

Therefore, there remains a question how a higher education institution should run the activities which aim is to move from a functional system to a process approach. The answer is not clear but it always depends on the decisions of the current authorities. The activities can be conducted in the direction of the measurement and the list of the results of the processes as much as the organizational structure of the university allows for it. However, one issue cannot be questioned- the modification of the organizational structure can be done at an extent which is allowed by flexibility of the authorities in the field of management [1, 21]. Therefore, all the changes in the strategic management of the university depend on the managers, their dedication, determination and a conviction of the rightness of actions. Unfortunately it can be supposed that a determination to strengthen the role of the strategy, a transfer to the following stages of the process maturity and finally the modification of the organizational structures will be relatively low because of the conditions of management connected with the term limits, changeability of the rules of operation imposed by the legal environment, organizational "heaviness" or an attachment to the academic tradition [22]. On the other hand, there is a stronger and stronger bottom-up reaction of employees who want to become the owners of the processes and the executors in the processes in which they can define in a clear way their impact on the value of the service provided by the higher education institution. This means that the administrative factors in the form of the provisions which oblige universities to create strategies and correct organizational structures stop to be important. The university which operates well must have a good strategy, a map of processes which helps to implement it and a structure of employment based on it. This is the right order to create a strong unit. The factor which determines such activities is first of all a desire to move to the process activities by people who want to be an element of the chain of the creation of values.

References

1. Wawak, T.: Dilemmas of the quality of management in a higher education institution. In: Sikora, T., Giemza, M. (eds.) Practice of Quality Management in 21st Century, pp. 253–272. Wydawnictwo naukowe PTTZ, Krakow (2012)
2. Bitkowska, A.: Management of Business Processes in a Company, pp. 155–159. Vizja Press&IT, Warszawa (2009)
3. Brajer-Marczak, R.: Performance of organization from the perspective of the model of process maturity. Manage. Financ. **10**, 513–523 (2012)
4. Grela, G.: Evaluation of the level of process maturity of the organization. Soc. Inequalities Econ. Growth **35**, 169–181 (2013). University of Rzeszow
5. Auksztol, J., Chomuszko, M.: Modelling of Process Organization. Wydawnictwo Naukowe PWN, Warszawa (2012)
6. Boszko, J.: Organizational Structure of a Company and Ways of Optimizing IT. Wydawnictwa Naukowo-Techniczne, Warszawa (1973)
7. Wawak, T.: A draft of the model of management improvement in higher educations. Sci. J. Wroclaw **264**, 451–474 (2012). University of Economy, Wroclaw
8. Piasecka, A.: Selected Aspects of Quality Assurance in a Public Higher Education Institution. Publishing House of University of Maria Curie-Sklodowska, Lublin (2011)
9. Kucinska-Landwojtowicz, A., Kolosowski, M.: Determinants of process maturity of the organization. In: Knosala, R. (ed.) Innovations in management and production engineering, pp. 655–663. Technical University of Opole, Opole (2012)
10. Mintzberg, H.: Management. Oficyna a Wolters Kluwer Business, Warszawa (2013)
11. Schermerhorn, J., Ehrlich, A.: Management: Key Concepts. Polskie Wydawnictwo Ekonomiczne, Warszawa (2008)
12. Gebczynska, A., Bujak, A.: Usage of the model of process maturity in the improvement of the systems of quality management. Sci. Pap. WSB **20**, 177–188 (2011). University of Wroclaw
13. Krzos, G.: Hybrid structures in the process organizations. Sci. Pap. Wroclaw **52**, 396–403 (2009). University of Economics
14. Grajewski, P.: Process Management of an Organization, pp. 123–133. Polskie Wydawnictwo Ekonomiczne, Warszawa (2012)

15. Kozminski, A.: Management: Systemic Analysis of Processes and Structures. Panst. Wydaw. Ekonomiczne, Warszawa (1977)
16. Kalinowski, B.T.: Analysis of business process maturity and organizational performance relations. Management **20**(2), 87–101 (2016)
17. Diagnosis of the condition of higher education in Poland. A partial report prepared by the consortium: Ernst & Young Business Advisory, Institute of Research on Market Economy (2009). http://www.nauka.gov.pl
18. Dziennik, U.: Law on higher education in Poland from 27th July 2005. Journal of Law No 164, 1365 as amended (2005)
19. Sokolowska, J.: Process approach to the management of higher education institution. Sci. Work WSB **14**, 231–242 (2011). University of Gdansk, Gdansk
20. Wawak, T.: Improvement of the quality of management in a higher education institution. In: Stabryla, A. (ed.) Improvement of the Management Systems in an Information Society, pp. 427–438. Wydawnictwo AE, Krakow (2006)
21. Wawak, T.: New trends in the management of higher education institution. In: Wawak, T. (ed.) Communication and Quality In Management, pp. 201–223. Wydawnictwo Uniwersytetu Jagiellonskiego, Krakow (2010)
22. Wawak, T.: Process management in a higher education institution. In: Skrzypek, E. (ed.) Influence of Process Management on the Quality and Innovativeness of the Company, pp. 61–72. Wydawnictwo UMCS, Lublin (2008)

ICT in Logistics as a Challenge for Mature Workers. Knowledge Management Role in Information Society

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Abstract. In Information Society the ICT competency are becoming more and more important not only for white-collar workers but also for blue-collar ones. Nowadays most of the economy sectors, such as logistics, cannot operate without ICT. For Millennials, who gowned up with technology, digital competency is somehow intuitive, but for older generations, especially for mature workers, ICT can be challenging. That is why a knowledge management in logistics companies can be a solution for competencies disproportion. The objective of this paper is to present the analysis of the scope of ICT competencies needed for employees in positions of logistics and to present the results of the analysis of the knowledge management in logistics industry. Presented conclusions of the study are the result of multi-faceted research conducted in 2012–2016 using grounded theory methodology.

Keywords: Mature worker · Logistics 4.0 · ICT competency · Knowledge management · Lifelong learning

1 Introduction

The technological revolution, which took place in the last two decades of the 20th century, caused a cascade of changes in key areas of social life. Technological progress, especially digital trends, may affect the competence required from workers in different industry sectors, such as logistics.

According to the Deloitte [1] and McKinsey [2] reports, in the field of Information and Communication Technology (ICT) can be defined the key trends, which significantly affect the pursuit of economic activities. Those trends apply to both: the technosphere, as for example the use of the vast amount of data available on the Internet, collecting of data in the "cloud", the widespread use of mobile devices or new forms of payment, and the social sphere, as interacting, socializing, communicating and working. Reliance on the user experience in the process of problems solving or the increase of the importance of e-commerce will also set requirements for logistics workers competencies.

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ICT competency is somehow intuitive for Millennials – generation borne between the early 1980s to early 2000s which grown up with technology. People born after 1980 are considered as “Digital Natives”, and they are significantly different from previous generation called “Digital Immigrants”. Millennials think, process information and communicate in very different way that for instance Generation X [3].

For older generations, especially for mature workers (55+), ICT can be challenging both in their private life, as well as in professional one. Mature workers learn much slower how to use new technologies and are not willing to adapt to new systems or change the ways of performing a job. Economic reasons very often not allowing spending enough time on training that is why mature workers need to face ICT challenge on their own.

2 Mature Workers in Logistics

Mature workers are the persons aged fifty-five and over (55+). Depending on the source, it can also be a person over fifty (50+), but in polish statistical studies age group 55–65 is specified, that is why in that paper a person 55+ will be considered as a mature worker. That age group of employees is still growing in Poland.

At the end of 2015 in Poland, among almost 17.5 million of economically active persons, 2.9 million were people 55+, which gives 16,6% of total. In that age group, 95% (2.8 million) were employed and only 5% were registered as unemployed persons. However, if that issue will be considered deeper, it can be noticed that population of 55 + in Poland is 11.3 million and 2.9 million of economically active persons gives only 26% of them. In that age group, 35.3% of men and only 18.9% of women are still active on the labour market. The age group of 45–55 years old economically active persons (3.7 million) is 21,4% of all economically active persons in Poland. The whole population of 45–55 years old is 4.6 million that means that economically inactive persons are 18% of that age group [4].

One of the answers, why the percentage of economically active persons in the group of 55+ is so low is the state pension age in Poland, which now depends on the date of birth. Nowadays women are retiring at age 60 and men at age 65. According to Polish government act form 2012 until 2040 pension age should be equal for men and women. Desirable level of 67 years will be reached for men in 2020 and for women by 2040 [5], but the current Polish government in 2016 passed a law lowering the retirement age to 60 for women and 65 years for men. However, going into retirement at age 67 will be still possible. Despite all those changes in last years, working age in Poland, according to Central Statistical Office methodology, is all the time 18–64 years for men and 18–59 years for women.

Nowadays, approximately 5.2% of economically active persons in Poland works in logistics industry, and it is definitely male workers dominate industry [4]. Most of work positions in logistics are now professional drivers, forklift operators, warehouseman, pickers, packers, etc., so the occupations with supremacy of physical work. Majority of the mature workers in logistics are employed as physical workers. In the group of specialists, 55+ workers are not so commonly employed. Logistics industry is still growing in Poland, as its real development started in 1990s, after the system transformation. Therefore, Polish logistics specialist have less than 30 years of experience on the Polish free market.

Nevertheless, core logistics is an intellectual work, so it needs people working on the position of analytics, forecasters, planners, specialist in the area of distribution, export and import, transport and shipping, warehousing, purchasing or supply chain. All those jobs do not have special physical requirements, so mature employees can perform them, under the condition, they have proper competencies, especially ICT competencies.

3 Research Methodology

In the studies, one of the qualitative research strategy – a grounded theory methodology [6] was chosen. This approach, rejecting theories conceptualizing before the test, is gaining more recognition among researchers of social phenomena, including in Management Sciences. In accordance with the rules of the method, before the start of the research no theoretical model was build, there were no axioms or assumptions. The hypotheses were being built and modified during research. The theory was appearing during empirical studies, based on data collected in years 2012–2016.

In order to be able to identify the problem and the emergence of the theory, it was necessary to collect systematically empirical data using a range of qualitative research methods and techniques. Both, the desk research and field studies were conducted. The study was divided into phases that allows gradually going into the topic and outlining the background of studied phenomenon and determining what further studies need to be carried out. The research results of each step in the study determinate the research carried out in a next step.

One of the objectives of the study was to determine the scope of ICT competencies needed for employees in positions of logistics. For that reason, in research selected logistic companies in Lodz Region in Poland were investigated. The Individual In-depth Interview (IDI) with managers, coordinators and HR specialist were conducted. IDI with representatives of 20 companies were conducted.

Moreover, survey were conducted with physical workers and specialists. The paper presents the results of the analysis of the needs for ICT competencies among all groups of employees: blue-collar workers, specialist and managers. The scope of the survey included the analysis of competencies possessed by workers employed on logistics positions, as well as competencies, which are key ones for these work positions. The aim of the survey was to analyze and evaluate the level of the ICT competencies of workers in the area of logistics, as well as an analysis of the ICT competencies required of these workers and the evaluation of the extent to which employees meet these requirements. The study involved 166 surveyed representing 40 companies. Survey was conducted among logistics workers employed at one of three levels of positions: blue-collar workers (22,9%), specialist (56,6%) and managers (20,5%). Although a group of physical workers was most numerous in each enterprise, those employees were the least willing to participate in the study.

Another research method used in study was Focus Group Interview (FGI) with logistics studies graduates starting professional career and with experienced logistics specialist and managers. Two FGI sessions with in total 25 logisticians were done.

Parallel to the FGI, analyze of the job advertisements for positions of logistics in the press and on the web portal was conducted.

The result of the study is the concept of the knowledge management, as a solution for competencies disproportion in logistics industry.

4 ICT Competencies in Logistics 4.0

Logistics of the future, like the entire Industry 4.0, will be based on new materials, nanotechnology, RFID technology or cyber-networks. “Smart” devices, products or packaging are becoming more and more popular and common. Such changes in technosphere cause the need for changes in social sphere [7]. The revolution in reversal of roles in the logistics systems is expected. A part of the executive work will be delegated to computers and other automatic devices [8]. In practice, that can mean that employees will perform organizational and conceptual tasks exclusively.

A particular challenge for employees of logistics is now navigating among the endless amount of information and using of a number of available data, which are crucial factor of market success of companies. The application of data warehouse turns out to be insufficient. Using of Big Data – large, variables and diverse data sets is an important challenge for logistics that requires continuous and in-depth analysis of constantly incoming information. Analyzing, evaluating, interpreting and inferring skills, which are crucial for logistics analytics, nowadays needs a support of ICT. Excellent ability to use Excel is basic ICT competency for logistic specialist in each area of logistics. Logistic analytics should be able not only use existing Excel tools, but mainly create new ones, according to appearing needs. If the age group 25–34 years old specialist assessed their Excel literacy as intermediate or even advanced, the age group 45–54 and 55+ assessed it as basic or even none. Mature and middle aged workers are not so fluent in Excel. They know how to create chart, sort tables, even create PivotTable, but designing simple macro or advances sorting and consolidating of data can be challenging. Among blue-collar workers knowledge of Excel is basic of none, but also nowadays there are no such expectations. According to job advertisement analysis, despite the development of ICT in logistics in last year, in 2011 in job offers for logisticians, in the requirements ICT competencies were not exchanged, even for specialist [9]. Today, they are commonly appearing in job offers for logistic specialist but they are usually not mentioned in job announces for blue-collar workers, and this is the group that feels a lack of ICT competencies the strongest.

Logistics specialists, who will use Big Data, need to possess the ability to use databases efficiently and effectively, but also will need the skills of analysis and synthesis of data. Contemporary polish education emphasizes the development of these competencies. In the world ranking of the countries in which graduates in education acquire competence of data processing and data analysis Poland found itself at the forefront. According to Programme for International Student Assessment (OECD PISA 2015) polish 15-years-old students were on 4th position in European Union and 13th in the world taking into consideration ability to understand and interpret the text [10]. So future workers will be better prepared to face the need of synthesis, analysis and inference data that are, apart from ICT competencies, crucial for logisticians.

The need for ICT competency in logistics comes also from, watched in recent years, development of e-commerce on Business-to-Consumer market. The ability to use existing tools, as well as the ability to design assumptions for new responsive and effective solutions will be required from logistics employees. The changes in the supply chain operating are also visible. The first noticeable change is the integration with customers and suppliers, thanks to the use of Electronic Data Interchange (EDI), or sharing data areas on the server, usually in the "cloud", which also requires ICT competencies.

Another trend in Logistics 4.0 is the Internet of Things (IoT). Application of the Internet of Things in the warehouse-logistics could allow even more effective and efficient work of automated warehouse that can work in three shifts, without generating additional personnel costs. IoT also allows for automatic inventorying of stock, as well as controlling the shelf life of the products. It also increases safety for operators, by automatically stopping the machines and devices, when a worker is in the danger zone [11]. Unfortunately, IoT can cause serious implications not only in the techno- and infosphere, but also in social sphere. Blue-collar workers, mainly pickers and forklift operators can be needless to executive work. Therefore, it is so important to take into account the new role of man in the warehouse-logistics subsystem and to find physical workers proper tasks. In Logistics of the future blue-collar workers will become younger specialist – qualified operators who, in a direct or indirect way, will coordinate and control the correct operation of the system. In that perspective, employees in the lowest positions in logistics, as well as the other employees, will require digital skills, so the ability to find, evaluate, utilize, share, and create content using information technologies and the Internet.

The role of the present physical employees in future will be the basic operation of the system, and therefore they will become the system operators. The role of the present specialists will be managing Big Data and creating new ICT solutions allowing making full use of the data, and therefore they will become analytics. Workers and specialists both will need to use ERP systems such as SAP, ORACLE or JDA or at least process data using Excel and SQL. The role of the manager will be making decisions based on the analyses carried out by a specialist and integrating different areas.

According to such a vision of the future of logistics, there will be a need for proper training of individuals who plan to take a job in the logistics industry, as well as there will be need for the improvement of the competency of the people already working in logistics, especially mature workers. Results of the study showed that in each of the researched group of logistics employees that kind of improvement were desired. In the group of physical workers, self-assessment of ICT competencies was on the lowest level. 55+ (even 45–54) executive employees assessed their ICT literacy as primary. Data input to the computer system was not a bigger problem, provided that there was available simple and clear instructions, and that task was routine. SAP system, or similar ones knowledge is also not so popular among Polish logisticians.

Even though, international experts from The World Bank as positive evaluate the state of the Polish logistics. According to The Global Ranking 2016 in 2016 Poland was on 33th position among 160 countries with the Logistics Performance Index (LPI) 3.43. World leader was Germany with LPI 4.23. The LPI is a benchmarking tool which purpose is to help countries to identify the challenges and opportunities connected with logistics activities but also to improve their performance. One of the parameters that was taken into account was logistics competencies: the knowledge, skills and attitude that people working in logistics should possess. Logistics competencies index for Poland was 3.39, when for Germany was 4.28 [12]. That shows that still there is a room for an improvement in that field in Poland, especially it the area of ICT.

5 Knowledge Management in Logistics 4.0

In Logistics 4.0 to minimize the ICT competencies disproportion between workers, wellsprings of knowledge – model of knowledge management can be applied. This model that is typical for Western countries, emphasize the explicit knowledge, so the one that can be codified in any database. Explicit knowledge is treated as enterprise the most important resource that gives a competitive advantage and it source can be both, a company and its environment. If the source of knowledge is out of the organization, it has to by import from the environment.

In the wellsprings of knowledge model the most important inside are core capability that can be identified as the core competencies, as they allow integrating the other components of the model, in connection with both, the interior of the organization and its environment. Core capabilities allow also for transition from "present" to "the future". Core technological capabilities, so those one that set the company apart from the competition, have four interdependent dimensions: employee knowledge and skill, physical technical systems, managerial systems, values and norms. Employee knowledge and skill that can be divide into three groups scientific, industry-specific and firm specific [13].

In logistics, industry-specific core technological capabilities in the dimension of knowledge and skill are:

- ICT competencies, understand as ability to constantly identify and locate resources of required information, to acquire and transform information for specific needs,
- analytical competencies, understand as ability to analyze, evaluate, interpret and infer information.

Wellsprings of knowledge model assumes, that organization to perform efficiently in problem solving but also in everyday operating needs to implement and integrate new methodologies and tools, also ICT tools, and experiment, that is, constantly improve and seek new solutions and of course share knowledge.

Analytical competencies, so ability to analyze, evaluate, interpret and infer information, are shaping in long-term education, mainly formal one. It is almost impossible to share that kind of knowledge in direct way, but it is possible to create and spread among company employees general procedure for dealing with a problem. The procedure should base on company interior experience and exterior good practices, remembering that own company experience is the most important.

Another solution helping mature workers dealing with challenges is to create a register of good practices consisting of examples of particular cases of problems or challenges that occurred in the company. Employee who has to solve a problem would be able to check if similar task/problem appeared in the past and how it was solved. In the register there should be information who was solving the problem and contact data to that person. That kind of register should be digitizes and accessible in the company intranet. For each described case there should be a place for open discussion and comments. If an employee interested in a case wants to personally (not on the public forum) asked about the case, there should be a possibility to sending an email directly being logged in the register itself. More over each person who is dealing with similar problem that described in register should mark it on the log of particular case. That kind of solution will not only allow employees to share knowledge, but also will let to know managers which cases are the most problematic and interesting. However, the way that an employee will use the knowledge about problem solving depends on the other employee's competences and intelligence. To use that kind of solution basic ICT competencies are needed.

The treat of this solution is the need to spend time on filling the register. Employees have plenty of tasks to do, and registering cases will be another time spending one, that is why they should be reworded for that activity.

Developing ICT competencies is easier and faster than sharing knowledge about way of analyzing, evaluating, interpreting and inferring information. That kind of knowledge should come from other employees. Advanced ICT users, so mainly the logistics specialist, do not have to share with blue-collar workers the knowledge about creating ICT tools, but they should explain how do they work and how worker should operate the system. If company employee creates ICT tool, he should train other workers who has to use it. Interface of the tool should be intuitive and should have built instruction of use, which is as simple as possible. The most effective instructions are video instructions, which connect visual instructions with voice ones. ICT tools users (operators) should not be able to damage the tool or change the way it operates. In the tool, there should be information who can help if the system is not operating. In that case, mature logistic executive workers can get rid of the fear of the using ICT.

With mature workers with a gap of ICT competencies who work or want to work as a logistic specialist knowledge sharing is much more difficult. As in Logistics 4.0 specialist will be managing Big Data and creating new ICT solutions they ICT competency has to be on higher level. Solution for ICT competencies sharing can be joining advanced ICT users (mainly "Digital Natives") with beginners (mainly "Digital Immigrants") into a pairs working together. In that case, training of ICT competencies will be a part of everyday work and not a separate activity. One the one hand advanced ICT users will be a sort of guide in digital environment, on the other matured experienced employees can share their professional knowledge with younger collogues. It is solution for both: new employed workers but also for already employed mature workers with a shortage of ICT competencies.

6 Conclusions

In the Information Society, logistics is based on three pillars: the processes, technologies and people. Unfortunately, new technologies commonly used also in logistics, increase the distance between young and mature workers by dividing them into operative users and those with digital skills gap, so who do not deal with new technologies. What is crucial, the success of the logistics companies comes from people who skillfully take advantage of the information making use of technology in all logistics processes. Therefore, logistics will need highly skilled workers with ICT competency, not only young ones, but also mature ones.

The logistics industry, although is not the most innovative sector, is increasingly dependent on ICT solutions, thereby needs employees which are experts users of ICT technologies. Logistics companies do not need to hire employees who will provide them new technical solutions, because they can get them from specialized R&D units, but need employees who will be efficient users of those solutions or will be creators of simple or advanced ICT tools.

Moreover, in the logistics of the future the share of physical work will decrease, and intellectual one will increase, therefore there will be more work stations, where longer occupational activity will be possible, but the condition to be able to work in logistics will be to have the ICT competencies.

A knowledge management in logistics companies can be a solution for competencies disproportion between workers, especially ICT competencies.

References

1. A wave of digital change: trends in digital. In: E-novation 2013, Deloitte (2013)
2. Big Data: the next frontier for innovation, competition and productivity. McKinsey Global Institute (2001)
3. Prensky, M.: Digital natives. Digit. Immigrants. Horiz. **9**(5), 1–6 (2001)
4. Statistical Yearbook of the Republic of Poland 2016. Central Statistical Office, Warsaw (2016)
5. Pension system in Poland. http://emerytura.gov.pl
6. Konecki, K.T.: Grounded theory. Studies in Qualitative Research Methodology. Wydawnictwo Naukowe PWN, Warszawa (2000)
7. Simon, W.: Blick in die Zukunft: Industrie 4.0. Ind. Eng. **2**(2013), 38–40 (2013)
8. Wyrwicka, M.K.: Revolution or evolution in logistics? Logistyka **3**(2014), 9–11 (2014)
9. Wrobel, M., Kwestarz, J., Majchrowska, A., Prusinowski, J.: Occupation: logistician – multifaceted analysis of the requirements for employees in positions of logistics in the Lodz Region. In: Gradzki, R., Sekieta, M. (eds.) Zarzadzanie procesami logistycznymi, Wydawnictwo Politechniki Lodzkiej, Lodz, pp. 211–236 (2012)
10. Programme for International Student Assessment. http://www.oecd.org/pisa/
11. Cornell University Digital Literacy Resource. https://digitalliteracy.cornell.edu
12. The World Bank. http://lpi.worldbank.org
13. Leonard-Barton, D.: Wellsprings of Knowledge: Building and Sustaining the Sources of Innovaion. Harvard Business School Press, Boston (1995)

Job Creation for People with Disabilities. A Case Study of a Concrete Batching Plant

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Abstract. Occupational activation of people with disabilities is one of the forms of their rehabilitation, and ensures their development and satisfaction of their social needs. The condition for employment of persons with disabilities is adequate adjustment of the workstation space and the workplace to match their abilities and accommodate their special needs. This paper reports on the analysis of the batching plant operator job and workstation with a view to adjusting it for many types of disabilities. Based on a checklist, types of disabilities which would not preclude the disabled from being employed in the job are identified. Next, physical load was estimated to determine if there are any contraindications for people with specific disabilities to work in the studied job. Based on the conclusions drawn from the research, adjustments are proposed for each type of disability. The process of workstation adjustment for people with disabilities and the research instrument can be used by enterprises in different countries, no constraints apply here, because all around the world, there are people with disabilities seeking employment.

Keywords: Person with disabilities · Workforce inclusion of people with disabilities · Workstation

1 Introduction

The challenge that we are facing today is to provide people with disabilities with appropriate conditions that would enable them to function in the society and prevent their isolation and social exclusion. It is essential to fully include people with disabilities in the family, professional and social life, which will make it possible for them to participate in every facet of life. Professional activity is the best way to achieve it. Work makes one feel self-sufficient and economically independent. It needs to be kept in mind, however, that employment must not exacerbate the disability in employees.

Therefore, proper job selection and organization of the workplace for disabled workers is crucial. Not every job can be adjusted to the abilities and needs of the disabled. It depends on many factors, e.g. the type and grade of a worker's dysfunction, the type of job, the conditions at the workplace, and the possibility of implementing

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technical and organizational changes. Before employing a disabled person, the employer needs to know the type and grade of the disability, to analyze the tasks of the job to specify the requirements for the employee at this post, and set the results of this analysis against the abilities and inabilities of the worker [1]. This study attempts to show how workplace adjustments in a concrete manufacturing plant can improve workforce inclusion of people with disabilities.

2 Study Objectives

The objective of the study was to assess how well selected jobs in a facility manufacturing concrete products were adjusted to the needs of disabled workers, and to propose changes that would have to be introduced in the workplace for a selected disabled person to be placed in the job.

3 Job and Workplace Description

Only males are employed as concrete batching plant operators. They operate concrete manufacturing machines.

The basic job requirements are: technical qualifications, at least secondary vocational school, certified to operate concrete-mixing systems (Class II Batching Plant Operator certification), computer literacy.

Typically, operators work an 8-hour (7am–3pm) one-shift schedule. Occasional overtime may happen in the summer months. Operators are entitled to one 30-minute break. All workers on a specific production line take this break at the same time. Operators are allowed to take a bathroom break at any time as long as they inform other workers on the same line because they will also need to take an involuntary break.

Throughout the shift, the operator performs the same activities. The number of repeated production cycles depends on the daily plan. During one working shift, single line workers can produce ca. 6000 concrete blocks or 500 sq. m. of pavers.

The production process includes the following activities [2]:

1. Maintenance check of the batching machinery: checking the electrical and control systems;
2. Computer-aided raw material dosing: sand, aggregate, cement;
3. Feeding raw materials into the automated batching system;
4. Dosing water and plasticizers;
5. Starting-up the mixer;
6. Mixing;
7. Overseeing the mixing process;
8. Transporting concrete to block machine bins.

The batching plant operator participates directly in activities 1 to 5 and 7.

The batching plant is comprised of:

– three aggregate batchers, 10 m^3 each (Fig. 1);

Fig. 1. Aggregate batchers [2]

Fig. 2. Belt conveyor [2]

Fig. 3. Silos [2]

Fig. 4. Planetary mixer [2]

– one ca. 10-meter long belt conveyor suspended on four tensometers that make it possible to weigh aggregate to an accuracy of below ± 0.5% (Fig. 2);
– two silos for cement and water storage (Fig. 3);
– screw conveyor for transporting cement and dry materials;
– automatic control panel (a PC coupled with a PLC that enable automatic control of the batching plant from the operator’s room; the control system allows the operator to save recipes and produce printouts compliant with EU directives) (Fig. 5);
– planetary mixer, 750 l dry filling capacity, with a skip (Fig. 4.);
– cement, water and admixture weigh batchers mounted above the mixer providing an accuracy of below ± 0.5%.

A concrete block machine for producing concrete products is connected to the batching plant.

The control room that goes by the name ‘trailer’ is the main task area for the batch plant operator. He spends about 6 h per shift there. From April to November, for about

Fig. 5. Batching plant control panel [2]

2 h per day, he oversees the process outdoors, whereas during the winter season, he oversees the operation of the block machine inside a production hall.

Cement, sand, aggregate, water and plasticizer are used for production of concrete products. Dye is added to the mix in the production of pavers.

Workers are not provided with working clothes by the employer. Their outfits are their personal matter, however, the employer requires that there be no loose-fitting pieces. Personal protective equipment provided by the employer are stoppers, protective gloves and dust masks. They are to be worn during the oversight of the mixing process as this when the worker has contact with cement, fly ash and plasticizer.

The batch plant operator works both in an open space (for about 2 h per shift) as well as in a closed space (for about 6 h per shift). In the closed space, the operator controls the process, whereas in the open space, he oversees it. The temperature in the room is about 20 °C. In summer, it depends on external atmospheric conditions, while in winter, it tends to be constant as the room is heated.

Average value of illumination intensity inside the control room equals 249 lx and exceeds the minimum of 200 lx required for this type of work. Illumination uniformity is 0.8 while the standard is 0.4.

Noise in the workplace is generated by the batching plant (the level of noise is 103 dB), vehicles serving the batchers, hoppers and bins (the maximum sound power of heavy vehicles at the start of the engine is 105 dB, and light vehicles - 97 dB), and the production hall located in the immediate vicinity of the batching plant (sound insulation of all walls of the building - not less than 20 dB; roof sound isolation - 18 dB; equivalent continuous sound level inside the hall within 1 m from each wall - 85 dB, and 75 dB for the roof).

The batching plant operator is exposed to cement, fly ash and concrete admixture during the oversight of the mixing process. Portland cement, Portland-composite cement, and Portland-fly ash cement are used at the plant. These types of cement are commonly used in accordance with the standard PN-EN 197-1:2012 *Cement – Part 1: Composition, specifications and compliance criteria for common cements*. Table 1 presents a classification of the substance.

Table 1. Classification of the mixture - cement [3]

Hazard category	Hazard description
2	H315 – causes skin irritation
1	H318 – causes serious eye damage
1B	H317 – may cause an allergic skin reaction
3	H335 – may cause respiratory irritation

Cement dust may cause irritation of the respiratory system. On contact with water, it may produce strong alkaline environment, which, in turn, may cause skin and eye irritation. Inhalation of cement dust may lead to health deterioration in people with respiratory conditions such as emphysema, asthma, or pre-existing skin or eye conditions. In the studied workplace, standard threshold values were not exceeded.

Fly ash is another substance. According to the provisions of the EC directive 67/548/EEC and Regulation EC 1272/2008, it is classified as hazardous [4]. Workers also handle fine and coarse aggregates, although they are not classified as hazardous or harmful to human health.

Plasticizer is one of the admixtures with which workers have contact. It is added to concrete to reduce its water content and improve its workability. The product has not been classified as hazardous, and is not dangerous for humans if handled in accordance with OHS rules [5].

4 Research Methods and Instruments

A modified version of the checklist developed by the Central Institute for Labour Protection – National Research Institute in the research project ‘Framework guidelines for workstation adjustments for people with disabilities with specific needs’ [6] was the main research instrument.

The instrument is comprised of two parts. Part one includes 46 questions concerning those characteristics of the analyzed job that could limit the possibility of it being performed by persons with a specific disability. The diagnostic response - yes - means that the checked characteristic can render the job more difficult for a person with a specific disability. The decision to employ the person should be made based on an analysis of his individual aptitude and psychophysical abilities [6]. Such personalized approach also orients part two of the checklist due to large discrepancies in the ability to perform the job in people with the same type of disability.

Part two, comprised of 99 questions, refers to seven aspects of the work environment that need to be considered when designing the workstation for the needs of people with a disability. These are: architectural and spatial organization of the workstation, lighting (including signaling lights), work space acoustics (including signaling sounds), electromagnetic fields and/or radiation, machines and devices, microclimate, chemical factors and physical loads. A ‘yes’ response in this part means that as far as this particular feature of the work environment is concerned, it is suitable for the person with the specific disability and there is no need to adjust it in this area. A ‘no’ response indicates that adjustment is required. In part two of the checklist one can choose ‘yes’, ‘no’ or ‘not applicable’ response. A ‘not applicable’ response means that the characteristic described in the question either is not present or is irrelevant.

Each of the diagnosed characteristics, in both parts of the instrument, is examined separately for the following types of disabilities: musculoskeletal, vision, and hearing impairments; mental disorders; intellectual impairments; disability resulting from systemic diseases (cardiovascular, respiratory, nervous, digestive, and genitourinary system diseases).

Some characteristics are not relevant in the context of workstation adjustment to the needs of people with specific types of disability, in which case the checkbox corresponding to the question has been blacked out in the instrument [6].

The original checklist had a number of errors. Therefore, it has been modified to a large extent by the authors.

For a few answers, the answer key had a number of errors. These were questions 18, 20, 24 and 30 in part I, and questions 38, 90, 97, 98 in part II. For these questions a (reverse-scored) answer key was used, which means that for part I questions, the diagnostic answer was ‘no’, whereas for part II questions, the diagnostic answer was ‘yes’.

The checklist includes questions that follow from previous questions and should be omitted if the answer to the previous question is negative (N), e.g. the question: ‘Are the means of transport used for business trips adequate for the needs of persons with disabilities?’ should be answered only if the answer to previous question: ‘Does your job require travel?’ was affirmative.

To obtain unequivocal answers, many questions are preceded with additional general questions or divided into two or more questions, e.g. the question: ‘Is a disabled parking space located next to the building entrance?’ is preceded with the question: ‘Is there a designated disabled parking space?’; the question: ‘Is the workstation lighting adequate for task performance and is the worker able to adjust it (e.g. workers with low vision)?’ was divided into two questions: 1. ‘Is the workstation lighting adequate for task performance?’, 2. ‘Is the worker able to adjust it (e.g. workers with low vision)?’.

As no information is available on the instrument’s standardization, it was only used for qualitative analysis.

In order to complete the checklist, workers and their superiors were interviewed and documentation review was performed.

Additionally, energy expenditure estimation was performed with the Lehmann’s chronometric - tabular method, static muscle load was assessed with the OWAS method, and postural load with the REBA method. Further, a review of substances with which batching plant operators have contact with was performed.

5 Analysis of the Possibility to Employ Disabled Persons and Adjustment Recommendations

Based on the study performed with the checklist, interviews and documentation review, characteristics of the analyzed job that could limit the possibility of it being performed by persons with specific disabilities were identified. The characteristics by the type of disability are summarized in Tables 2 and 3.

Table 2. Characteristics that could limit the possibility of the job being performed by people with specific disabilities identified on the basis of part I of the checklist [2]

Type of disability	Characteristics of the analyzed job limiting the possibility of employment of a person with a specific disability
Musculoskeletal disorders	- working overtime (occasionally, in the summer months); full function of lower limbs required; fully functioning equilibrioception; work at height; work involves machinery operation; outdoor work
Visual impairments	- working overtime (occasionally, in the summer months); fully functioning equilibrioception; work at height; machinery operation; exposure to harmful substances (occasionally, during the oversight of the production process)
Hearing impairments	- working overtime (occasionally, in the summer months); work requires verbal communication; fully functioning equilibrioception; work at height; machinery operation; constant verbal contact with coworkers; exposure to harmful substances; noise exposure
Mental disorders	- working overtime (occasionally, in the summer months); workstation isolated from others (worker is alone at his workstation and can only radio-communicate with coworkers; sole responsibility; exposure to harmful substances; noise exposure
Intellectual impairments	- working overtime (occasionally, in the summer months); workstation isolated from others; sole responsibility; demanding job requiring longer job training; work involves operation of many machines; exposure to harmful substances; noise exposure, outdoor work
Disability resulting from systemic diseases[a]	- working overtime (occasionally, in the summer months); workstation isolated from others (III); fully functioning equilibrioception (III); work at height (III); machinery operation (III); exposure to substances causing allergic reactions and irritating respiratory system (II); exposure to harmful substances (I-V); outdoor work – about 2 h/shift (I, II, V); noise exposure (I)

[a] (Cardiovascular system (I), respiratory system (II), nervous system (III), digestive system (IV) genitourinary system (V)).

The summary presented above implies that a person with lower limb disability may not be employed in the studied job. This results primarily from the requirement for working at height, frequent use of the stairs, both of which cannot be eliminated. Moreover, there is no possibility of expanding the working space to improve maneuverability. Upon consultation with an occupational medicine specialist, the possibility of employing a person with an upper limb disability could be considered because none of the activities performed at the workstation requires their full functionality.

Persons with visual impairments will not be able to work as batching plant operators. Apart from the stairway and work at height, the greatest problem for them would

Table 3. Characteristics that could limit the possibility of the job being performed by people with specific disabilities identified on the basis of part II of the checklist [2]

Type of disability	Characteristics of the analyzed job limiting the possibility of employment of a person with a specific disability
Musculoskeletal disorders	- public transport stops are not in the immediate vicinity of the plant (they are 1 km away); - no designated disabled parking spaces (interview with an employer representative, and personal observation, allowed me to confirm that there is enough space on the premises to designate such space); - entrance door width 0.8 m; - no elevator to transport people from floor to floor or any other lifting devices; - stairway steps may cause stumbling and catching; - stairway landing dimensions are not 1.5 × 1.5 m and it is located within the parameter of the door wing swinging open; - stairway railings are taller than 0.9 m; - light switches are at the height of more than 1.2 m; - there is no accessible toilet in the building; - at the nearest toilet, there is no maneuvering space (min. 1.5 × 1.5 m), the toilet bowl is not accessible from both sides, there are no grab bars, the floor surface is not slip-resistant; - restroom doors are not marked with informational pictograms; - in the work room there is not the minimum 1.5 × 1.5 m maneuvering space, and there is not a minimum 1-meter wide access way to the workstation; - there is not a possibility to adjust the desk to the height of the worker, and the desk itself has no border to stop object from falling; - there is no room at the workstation to place mobility aids securely (crutches, walkers)
Visual impairments	- public transport stops are not in the immediate vicinity of the plant (they are 1 km away); - no designated disabled parking spaces; - entrance door is not visible at all times of day; - a stairway leading to the workstation is not marked with stripes whose color would contrast with the colour of the floor, which may cause stumbling, and the landing is in the parameter of the door wing swinging open; - light switches are not distinguished with a different colour; - floor surface in the restrooms is not slip-resistant; - doors to sanitary rooms are not labelled; - rooms on the premises are not labelled; - lighting at the workstation cannot be adjusted; - in an emergency, there is no light or vibration alarm signalling;

(*continued*)

Table 3. (*continued*)

Type of disability	Characteristics of the analyzed job limiting the possibility of employment of a person with a specific disability
	- machinery and equipment operation manuals are not printed in large font/ Braille; - the surface of the desk is not secured to prevent object from falling off, and the desk corners are not rounded; - there is no room at the workstation to place mobility aids securely; - the software used in the job is not adapted to the needs of legally blind people, and there is no possibility to personalize the font; - the control panel has large buttons but small captions, which makes reading them difficult for a low vision person. The same applies to the software application with preset font
Hearing impairments	- no vibration signalling in emergency situations; - communication between sign language users and hearing people is not provided for
Mental disorders	- there is no room in the building to take medication
Intellectual impairments	- public transport stops are not in the immediate vicinity of the plant (they are 1 km away); - sanitary rooms are not labelled
Disability resulting from systemic diseases[b]	- no designated disabled parking spaces (I-V); - no accessible restrooms (IV, V); - no labelling of sanitary rooms (IV, V); - desk corners are not rounded (III); - no designated room to take medication (I-V)

[b] (Cardiovascular system (I), respiratory system (II), nervous system (III), digestive system (IV) genitourinary system (V)).

be the absence of the possibility to adjust the software and control devices to the individual needs of the worker.

People with hearing impairments cannot be employed in the analyzed job either. What absolutely excludes them is the fact that the job requires fully functional equilibrioception and verbal communication with coworkers.

Due to the isolation of the workstation from others (the worker is alone at the workstation and only can radio-communicate with coworkers) and heavy responsibility resting with the worker, employing people with mental disorders or intellectual impairments is not recommended. People with mental disorders are also excluded by the fact that the job is complex (requires operating many machines) and involves more extensive job training.

In the case of disabilities resulting from systemic diseases, people with nervous system disability are absolutely excluded. Employment of a person with a respiratory system disability will depend on the physician who will decide whether the present dust exposure levels could be harmful to the health of the candidate for the job. Similarly, for a person with genitourinary system dysfunction, a physician should decide whether working outdoors in the months of April to November may exacerbate the dysfunction. It is highly probable that persons with specific cardiovascular or digestive system dysfunctions could work as batching plant operators provided that the job will not demand non-physiological, prolonged stress positions; cause overload of the static-dynamic system; place people under mental and emotional pressure; cause excessive energy expenditure [7].

To determine physical load, energy expenditure was estimated with the Lehmann's chronometric - tabular method, static muscle load was assessed with OWAS and postural load with REBA. Test results should allow occupational medicine physicians to make a decision concerning employment of a person with disabilities.

Overall energy expenditure per shift (480 min) may amount to 850 kcal, which classifies this job somewhere between light and medium heavy work for males. The average energy expenditure per minute ranged from 1.5 to 2.4 kcal/minute and was regularly distributed during the shift. During the study, no activities were observed that would cause energy expenditure peaks of above 5 kcal/minute.

The static muscle load was small because the category of static load for all worker postures equaled 1, there were no stress positions, and the time they had to be held did not exceed 70% of the working shift.

The assessment of the postural load with REBA did not indicate that adjustments should be required at the workstation. The risk of a musculoskeletal overload was low for all performed activities [2].

The study shows that there are disabilities which do not preclude a person who suffers from them from undertaking the job under analysis - cardiovascular, digestive system, and upper limb disabilities. However, for each case, adequate adjustments would be required, e.g. for people with digestive system dysfunctions, working overtime would need to be eliminated, the number of breaks should be increased if necessary, a room where medication could be taken should be designated, paramedic assistance should be provided. Further, a disabled parking space should be designated, and if necessary, the sitting chair should be replaced with a more ergonomic one. It needs to be borne in mind, however, that the final decision on employment conditions should be taken by an occupational medicine physician who will take into account individual needs and abilities of the candidate for the job. Moreover, the company that is interested in employing people with disabilities should provide adaptive training for each new employee to introduce them to the principles of co-working with disabled persons including the potential difficulties associated with the disability of particular coworkers, and training for managers on disability management in the workplace that would tackle the issues of worker diversity and individualized approach to the worker, preferably delivered by an external provider. This would improve the comfort of work both for the disabled workers and for the non disabled ones [8]. As far as people with digestive system dysfunctions are concerned, the adjustments introduced in the workplace would be minor, mainly organizational, although for other diseases, more expensive technical changes might be required.

6 Conclusions

The paper presented the process of creating a workstation for a person with disabilities by adapting an already existing one. First, the workplace was characterized and the qualification required for the job of a batching plant operator were specified. Next, the types of disabilities that allowed the disabled to work in the job were identified with the checklist and other additional methods. All disabilities will require organizational or technical adjustments at the workstation. The next step to take when a person with disabilities applies for the job is to check whether the person will indeed be able to meet demands of the job (to analyze the person's abilities and disabilities against the demands of the job). If the person is found to be able to work in, changes should be introduced to adjust the workstation to the individual needs of the person.

The proposed process of creating the workstation for people with disabilities and the research instrument may be used by enterprises in various countries, no constraints apply here, because all around the world, there are people with disabilities who are looking for work.

One condition for the successful completion of the process is a state where at the same time, at the same place and under auspicious external circumstances (legal and organizational determinants), the person with disabilities has the internal motivation (the need) to work, has the capacity (attributes) to perform the required work tasks, whereas the employer has certain human resources needs and is willing to take the decision to employ an interested disabled person having first analyzed the situation, especially, the balance of additional costs and benefits that employing a person with disabilities may entail [9].

References

1. Polak-Sopinska, A.: General principles of matching jobs to individual abilities of people with disabilities. In: Lewandowski, J., Lecewicz-Bartoszewska, J., Boczkowska, K. (eds.) Ergonomics for People with Disabilities in Work Organization and Medicine, pp. 103–104. Department of Production Management, Lodz University of Technology, Lodz (2007)
2. Bernacka, A.: (thesis) Adjustment of selected work stations for people with disabilities in production enterprise "Mordaka". Scientific promoter: Ph.D. Polak-Sopinska, A.: Faculty of Organization and Management, Lodz University of Technology, Lodz (2016)
3. Cement Product Data Sheet. www.lafarge.pl/Cement_Product_Data_Sheet.pdf
4. Substance Information Sheet: fly ash. http://nse.com.pl/wpliki/arc-mastersis-boiler-slag-pdf_315_398.pdf
5. Ferro-plast Product Data Sheet: plasticizer. http://www.ferrokolor.pl/res/serwisy/ferrokolor/komunikaty/_002_005_001_34704.pdf
6. Central Institute for Labour Protection – National Research Institute, Checklist for assessing work environment for the needs of people with disabilities, pp. 1–3. CIOP-PIB, Warsaw (2014)
7. Gorska, E. (ed.): Designing Workstations for People with Disabilities, p. 60. Warsaw University of Technology, Warsaw (2007)

8. Adjustment of facilities, workspace and workstations for people with disabilities with special needs – good practices, p. 208. CIOP-PIB, Warsaw (2014)
9. Barczynski, A.: Creating and adjusting jobs for people with disabilities – issues and recommendations. In: Lecewicz-Bartoszewska, J., Lewandowski, J. (eds.) Ergonomics for People with Disabilities – everyday life inclusion. Prevention, rehabilitation through work and education, pp. 34–35. Lodz University of Technology, Lodz (2013)

Labor Ergonomic Analysis Applied to a Brazilian Solid Materials Recycling Cooperative

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Abstract. The key to successfully develop a program to enhance safety and ergonomics in the workplace is an innovative process that aims to reduce workplace injury levels as well as minimize risks. This can be achieved by raising awareness and changing employees' behavior. Nowadays managers tend to strive for improved efficiency and productivity in all sectors. However, the growing demand for greater productivity has put the employees' health and well-being at great risk. Following another trend, the enterprise under study is based on the principles of solidarity economy that aims to guarantee self-management processes, focusing on the human health and wellbeing rather than financial profits. Based on the ergonomic questionnaire results and the follow-up of the co-workers' routine, some forms of improvement to accomplish their tasks were suggested.

Keywords: Human factors · Solidarity economy · Ergonomic analysis

1 Introduction

Solidarity economy has spread as a possibility of survival by population segments excluded from the formal labor market. It manifests itself in different organizational forms built upon general principles of self-management, characterized by more democratic decision-making, social relations of cooperation between people and groups, and horizontality in social relations in general [1]. This possibility establishes, therefore, a "new" form of production, consumption, and distribution of wealth centered on the value of the human being, building an alternative to the alienating dimension of dehumanized work. It also includes a multidimensional character, involving social, economic, political, ecological, and cultural aspects, in the perspective of building a fair and sustainable society.

The work with this recycling cooperative raised the need for reflection on the issue of health and ergonomics in the work developed by these cooperatives. This is because the construction of self-managed relationships does not in itself assure safer working conditions, especially in view of the daily urgency for securing a minimum subsistence income. Thus, the precarious structural conditions and the risks faced in everyday work

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in this association indicate that the issue of ergonomics, health, and safety is pivotal also in solidarity economy projects.

According to [2], ergonomics is the study of the relation of man and his work, equipment, and environment, and the application of knowledge from different areas in solving problems that arise from this relationship. Ergonomics is divided into three specific characteristics, which can be addressed as physical, cognitive, and organizational ergonomics.

All subdivisions of ergonomics are integrated in today's organizations without neglecting efficiency and productivity. Thus, in the classical method of activity ergonomics, ergonomic analysis of work has been consolidated in the labor sciences as an effective instrument to operationalize the perspective of understanding work in order to transform it [3]. From a contemporary point of view, the world of labor is undergoing accelerated transformations associated with a productive restructuring process with negative indicators on the health and safety of workers. Examples include work-related epidemics of musculoskeletal diseases, cases of burnout syndrome, and an increase of work accidents [4]. The sense of intensification of work, with performance at the limit of capabilities, has become more and more common in workers' reports.

Although relative to productive processes, in which the worker is in a subordinate condition, the rupture with the mental suffering to which workers have already been submitted by their previous experiences of dehumanized work, is one of the major challenges faced by solidarity economy projects [5]. Despite of the challenge, this reflection cannot be avoided, given the risk of replicating in cooperatives the precarious conditions and health risks found so often in production-driven organizations. Thus, it is relevant to penetrate into the daily life of these subjects, to understand the meaning they attribute to their own work, as well as to perform a profound evaluation of ergonomics, health, and work safety aspects.

2 Methodology

A preliminary analysis was carried out to choose the most suitable method to achieve the best results with respect to the reality of cooperatives.

The inductive method was adopted, with emphasis on a descriptive approach to develop first a qualitative analysis and then a quantitative survey corresponding to the field of study of the work. Descriptive research seeks to discover, as precisely as possible, the frequency of a phenomenon, its relation and connection with others, as well as its nature and characteristics.

Based on these factors, a descriptive study was developed supported by a survey and interviews with employees of a cooperative to gather information about their feelings and perceptions regarding ergonomics. A total of 10 cooperative workers were interviewed during the development of their tasks.

Assessment of the workplace was carried out through visits to the cooperative during working hours to record the real routine of a worker in the cooperative's space. Thus, monitoring was performed in such a way that allowed the perception of the real conditions and challenges faced in this sector.

After this observatory phase, relevant information was recorded concerning the working environment of the cooperative during separation of recyclable material.

Based on this assumption, a 10-question survey was applied to the workers to seek a qualitative knowledge of the work environment of the company that contributed to the ergonomic understanding of the operations. Next, workers from sorting, fine material disassembling, and loading and unloading of material, were interviewed to obtain more information about the general context of the separation, such as the difficulties faced in the process, characteristics of the posture at work, workload, productivity, and ergonomic concerns within the organization.

The administered survey was adapted from [6], which represents an elaborate tool allowing the worker to express his/her perception regarding the workplace and the activity performed, informing whether he/she feels discomfort, difficulty or fatigue, in what intensity, and whether this is related to the work executed. The number of questions of the survey was reduced from 11 to 10. The survey was administered orally, taking into account the accelerated work routine and the personal effort of each cooperative worker, thus, avoiding any pauses during working hours. In addition, due to the low level of education of the workers, an oral survey eases the understanding of the questions and provides a more realistic response.

The data were submitted to a qualitative analysis, defined by parameters described in the literature. Using the level of satisfaction and/or dissatisfaction of the worker with respect to the degree of difficulty and/or ease pointed out by the information relative to the study environment, it was possible to verify some aspects of the man-machine-environment interaction fundamental to ergonomic analyses.

3 Results and Discussion

This section deals with aspects of work organization and the results and discussions regarding the administered survey, with the aim of identifying the main regions of the body affected by pain and discomfort, as well as to detect work situations more likely to cause injury.

The results allowed the development of proposals to promote a process of search for ergonomic improvements in several tasks, in order to preserve the health and improve the comfort and well-being of the cooperative workers during the working hours.

3.1 Ergonomics in the Cooperative Work

The information gathered from the visits and monitoring of the cooperative workers' routine in the work space was sufficient to trace some aspects of the ergonomic reality in this sector of production. Techniques and methods used in the areas of sorting, pressing, and loading and unloading of recyclable materials were observed and recorded.

The first noticeable impression was the non-use of personal protective equipment (PPE) by a large number of cooperative workers in the different production stages. It was clear that some of the workers use PPE and maintain an adequate level of safety, aiming at preventing accidents and unhealthy situations. However, others do not use

PPE and show a lack of interest in their use. This practice has a great influence on the final outcome of the operations, since adoption of suitable safety measures could prevent accidents. Moreover, this would allow decreasing the risk of accident and discomfort inherent to the nature of the task performed.

The PPE routinely neglected by most workers was the protective respiratory mask. Respiratory masks are essential for workers to handle materials with odors and biological agents. In addition, there is dust and animals in the workplace that can transmit diseases. Most workers use gloves that prevent against pathogens, glass cuts, metals, and pointed objects (puncture-sharp). These also offer some protection to chemicals, mitigating and preventing to some extent the occurrence of accidents. However, there is a lack of safety in the unloading of the unseparated materials, since it is not possible to have prior knowledge of the type of material present, causing several accidents in the lower limbs (legs). This makes it necessary the use of leather shin guards that can prevent the contact of legs with any type of perforating object.

With respect to workers who wear gloves and work with PPE in the dismantling of parts (Fig. 1), they can still be found working in awkward positions and tend to strain the spine, exposing the body to an irregular labor. Due to the absence of adequate furniture the conditions are precarious, typical of the adaptation of man to work in situations of complete discomfort, aiming only at productivity. Although initially the financial results overcome the labor difficulties, in the long term the worker is not able to maintain its productivity, entering into decline.

Fig. 1. Cooperative worker disassembling parts.

Thus, weariness associated with the repetition of inappropriate postures interferes directly in the personal productivity and later on the whole group's productivity, since the former affects the cooperative's business, impacting on the collective profits. The permanence of the worker for long periods in this position causes the loss of labor capacity in the long term, in addition to exhaustion during the working day. Another noteworthy point concerns the non-use of uniforms and adequate PPE, thus, bearing some parts of the body totally unprotected during activity.

Fig. 2. Cooperative worker bent during materials sorting.

These same postures can be observed in several other stages of the separation process, causing discomfort and weariness to the upper areas of the body, such as the cervical spine, lower back, shoulders, and arms (Fig. 2). The discomfort caused by prolonged exposure to an improper position may cause physical exhaustion and pain that may impair the worker's personal productivity. This situation should be mitigated by the use of workbenches and/or conveyor belts to facilitate the movement of materials and improve the posture of workers throughout the handling of recyclable materials and other equipment.

During the pressing stage, workers bend the body forward to force the recyclables into the machine, which causes discomfort in their spine (Fig. 3).

Next the workers tie the load in a harmful position and remove the load from the press in an irregular crouched position, using force to open the press machine.

Fig. 3. Cooperative workers operating the press.

The more uncomfortable and exhausting the operation, the slower and unproductive the worker becomes, compromising the pressing time and reducing the material flow.

After the separation stage, it is common to observe workers pulling bags filled with material to the loading area near the vehicle which collects the separate materials for sale. The workers carry the bags with their arms turned back further damaging the cervical spine, lower back, shoulders, and arms. Next, the bags are loaded into the transport vehicle.

This stage is a period of great pain and physical effort for the workers. They have developed a particular method for strategically allocating all the bags on the top of the vehicle. This requires a worker on the top of the vehicle to pack the bags, while at least two other are responsible for lifting the bags from the ground level with their arms (Fig. 4).

Fig. 4. Loading of the bags for sale.

This operation demands extreme strength of the workers, who in turn do not adopt safety measures. Furthermore, this operation exposes the worker on top of the vehicle to the risk of falling while the others are forced to inhale dust and several microorganisms present in the environment. The accomplishment of this task demands a risk evaluation, platforms, and the use of a safety belt to work at height in compliance with the Brazilian regulatory norms, which are not properly respected.

Throughout the entire production line, materials are separated and concentrated; those with no commercial value are discarded for waste. This operation forces the workers to carry the objects through long distances either pulling them in large containers (Fig. 5), or using improvised carts.

Both methods expose workers to inappropriate physical efforts and postures, causing pain and fatigue. This practice damages the lower back, arms, and spine, directly affecting the worker's productivity.

Fig. 5. Cooperative associates transporting materials.

3.2 Application of the Ergonomic Survey

Application of the ergonomic survey allowed establishing a relationship between the worker's tasks and the parts of the body affected by discomfort and pain establishing a link with a specific work sector. Further, the qualitative and quantitative approach used allowed to analyze and evaluate some factors related to the non-application of the best ergonomics practices:

- Tenure at the cooperative;
- Workload;
- Relationship between discomfort/pain and work;
- Region of discomfort;
- Intensity of discomfort/pain;

With regard to the first factor, "tenure at the cooperative", there is a probable relationship between the time workers are associated with the cooperative and the existence of more intense discomfort/pain in several, upper and lower, limbs.

Concerning "workload", in general all cooperative workers work 8 h per day and 4 h at the weekend, totaling 44 h a week. No influence of this factor was identified on the evaluated problems.

With respect to the "relationship between discomfort/pain and work", most of the workers answered that discomfort/pain is related to the current work sector. The ratio of workers who believe that pain is directly related to the work sector is shown in Fig. 6.

Regarding the "region of discomfort", the great majority of the workers presented discomfort and pain in three regions, the spine, shoulder, and legs according to Fig. 7.

Finally, concerning "intensity of discomfort/pain", most of the respondents felt a moderate or a slight discomfort/pain, with the exception of a worker who was in severe pain during the interview (Fig. 8).

Based on the present combined qualitative and quantitative approach together with the descriptive analysis, measures will be proposed to improve the ergonomic aspects

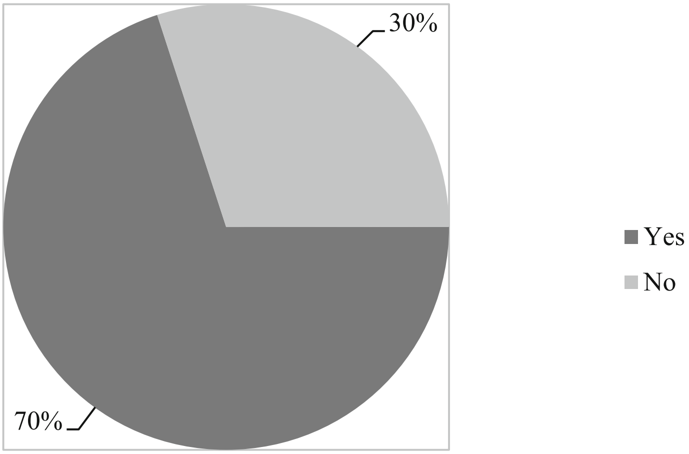

Fig. 6. Percentage of the workers who associate the discomfort with the work sector.

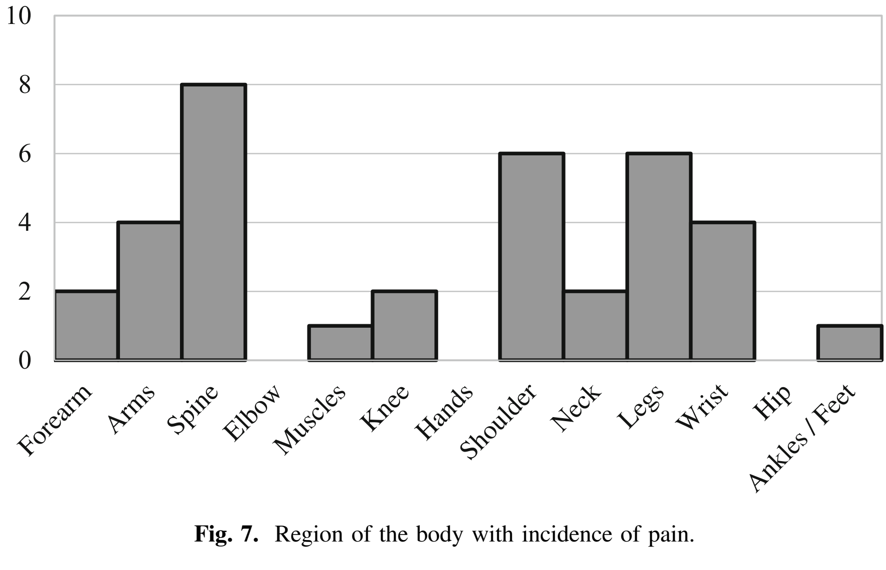

Fig. 7. Region of the body with incidence of pain.

of cooperative work, aiming at a reduction of the discomfort, pain, and health problems due to the ergonomic posture adopted during work hours.

Examples of these measures include the creation of break times during the day for rest and hydration, the implementation of gymnastics at work, and the adaptation of mats and movers for the transportation and movement of materials. These measures will probably be well received by the cooperative workers in view of the lack of adequacy of the activity throughout the productive process.

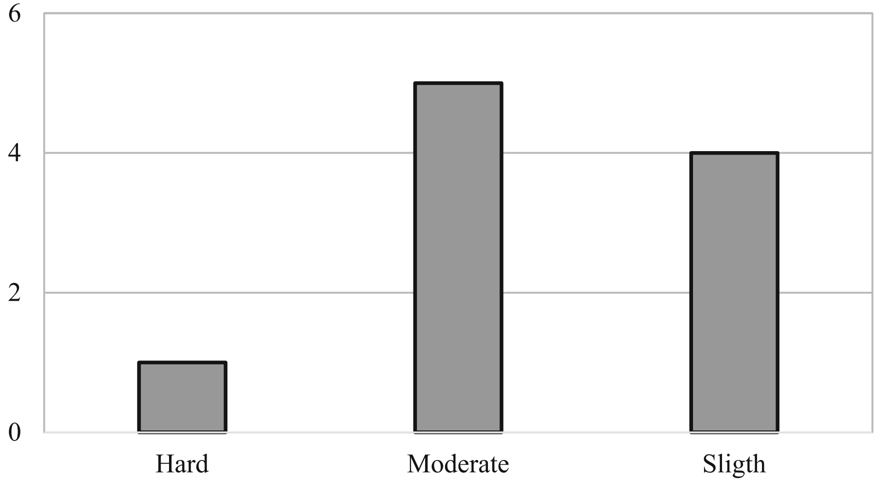

Fig. 8. Pain intensity.

Finally, an ergonomic improvement aimed at increasing productivity and the well-being of the workers, further reflecting on the cooperative's financial gains, is expected to be achieved after this study.

4 Conclusions

This study shows that application of ergonomic concepts allows establishing a correlation between the injuries and problems in the workplace of a cooperative of recyclable materials. This is because the interference of a subject changes directly the context and efficiency of the other.

Each cooperative worker is primarily responsible for itself and the way it operates. However, this impacts on the overall productivity of the cooperative. Thus, every cooperative worker is asked to produce satisfactorily in compliance with acceptable standards. This will not hamper total productivity, adding value to the organization's members, controlling operations, fostering well-being, and the personal and group satisfaction within the organization.

Through this study, it is possible to understand the lack of understanding on the need to protect health and to work under acceptable ergonomic standards, preserving physical integrity, avoiding accidents, and exposition to risk situations. Ergonomics is neglected, precarious, practically ignored, and the tasks are developed in a totally artisan way, adapting man to work without considering the health aspects of the cooperative workers.

The culture of self-preservation and zeal for productivity within the workplace is lacking, given the scarcity of resources and the inadequate working conditions present in this activity sector.

The reality of the cooperative members is challenging, causing workers to worry about several issues such as the type of materials handled, work hours, labors, productivity, and remuneration. However, there is room for improvements, provided the need to exercise heavy labors is overcome by the will to rethink processes to solve difficulties and apply improvements in the daily life of the cooperative. Ergonomics in the sector of recyclable materials cooperatives is a fundamental tool for the recovery of workers' dignity, preservation of health, and the achievement of ideal productivity.

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References

1. Coutinho, M.C., Beiras, A., Picinin, D., Luckmann, L.: New paths, cooperation, and solidarity: psychology in solidarity projects. Psychol. Soc. **17**(1) (2005). Porto Alegre
2. Iida, I.: Ergonomics: Design and Production. Edgard Blücher, São Paulo (1998)
3. Ferreira, M.C.: Activity ergonomics applied to quality of life at work: place, importance, and contribution of the ergonomic analysis of work (AET). Braz. J. Occup. Health **18**, 18–29 (2014). Springer, Heidelberg
4. Ferreira, M.C.: Quality of life at work. A Workers-Centered Approach. Edições Ler, Pensar, Agir, Brasília (2011)
5. Brancaleoni, A.P.L.: Health and Safety at Work in a Recycling Association of Jaboticabal-SP, VII Seminar on Workers Health and V Seminar the Work on Debate "Work-related Mental Health" (2010)
6. Couto, H.A.: Ergonomics of the Body and Brain at Work. Editora Ergo (2014)

Soft Skills and the Construction Site Manager: The Chameleon Professional

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Abstract. The gaps between the skill levels of construction site managers are widening. Projects are becoming more complex and eventually too demanding. This hampers construction site management professionals in the effective management of projects. The construction industry need to keep up with society's demands by ensuring that industry selects the best students and retains them once they have gained experience. Highly skilled construction site managers are often lured away from the construction environment to other industries, through higher salaries, better work conditions and work-life balance. The Baby Boomer generation is slowly exiting the construction industry, taking with them their critical skills and leaving no replacements. The aim of this study is to establish a profile for the typical construction site manager in South Africa based on current day-to-day industry requirements. The methodology included practical case studies that were used to illustrate that Melvin's professions list were the results of eleven typical soft skills, and could be interpreted through Bono's six thinking hats. Literature research was conducted on each overlapping soft skill. A construction management student owns certain soft skills which can be identified and developed into a quality that gains significant improvement. When the construction managers use these soft skills to manoeuvre between the six thinking hats of Bono, his/her effectiveness on a construction site will increase. Previous work experience will also influence the level on which he/she can optimise Melvin's different professions. Useful recommendations were made, i.e. the importance of cultivating soft skills in a construction manager; the importance of the ability of the construction manager to interchangeably apply these softs skills in combination with the six thinking hats; the level of ease with which the construction manager can balance everything will impact his/her effectiveness on the project; the margin of increase of production will be partially dependent on the construction managers' level of effectiveness; and lastly, a proper tertiary education in construction management and vast practical experience is not only important, but also essential. Purpose-fit candidates may have to be headhunted from as early as school level. They can be presented with bursaries and a guarantee of employment after completing their studies to assist in creating a pool of purpose-fit candidates that are more likely to stay and grow in the industry.

Keywords: Construction manager · Soft skills · South Africa

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1 Introduction

The construction site manager plays an indispensable role in the construction phase, coping with the difficult dynamics of an ever changing industry to fulfil the required project goals [1]. There are many other professionals involved in the construction life cycle, but it is only the construction site management team that creates something tacit [2].

Construction management is about getting things done properly throughout the whole construction project [3]. Fryer (2004) further states that a construction manager must be able to forecast, plan and control the work, as well as indicate how these processes should be carried out. While conducting and controlling work, construction managers also need to lead their teams, have sound technical knowledge of construction, be dedicated, experienced, have a strong character and perform well under pressure [4].

The lack of experienced construction site managers saps the delivery of projects within the specified time, cost and quality [5]. The construction industry faces challenges to attract and retain skilled construction site managers. Lucrative international opportunities and opportunities in industries successfully lure skilled construction site managers away. The aging workforce, comprised of the Baby Boomer generation is steadily being phased out; years of irreplaceable experience are lost. The unattractive image of the construction industry doesn't aid the situation, leaving inexperienced generation-y employees to rise to the occasion to fill the experienced footsteps of the phased out Baby Boomer generation [6].

While years of practice on site will eventually lead to appropriate skills through experience, there is a need for accelerated learning to improve the skills of the generation-y to meet industry demands; yet these skills for a successful construction site manager are currently not well defined. It should be emphasised that the selection of required skills is as defined and purpose-fit as possible.

According to Melvin (1979) [7] the psychological aspects of construction management may be the difference between the success and failure of a project.

Finding and ensuring a continuous flow of excellent construction site managers who could contribute to both the performance of projects and the construction industry at large, makes it imperative to understand the dynamics of human interactions. There is no debate around the fact that construction site managers' efforts have a direct impact on the productivity and quality of the work to be completed. Employees whose jobs do not fit their personality profiles are not likely to add value to their company [8]. The actual value added will largely depend on the quality of the match or fit that is established between employees, their work, the organisation, and the environment [9].

A study from Othman *et al*. (2014) [10] summerised the skills and competencies (using various sources) that a construction manager graduate need to obtain. The construction site manager needs to be intelligent, flexible, adaptive, competent and have the ability to deal with uncertainty and rapid change [11]. Melvin (1979), has summarised a construction manager as someone who needs specific skills different from those seen in different professions.

From the above, it can be seen that there is little consensus on the required skills and competencies of a successful construction site manager. Lack of success can however have devastating consequences, as shown by the high failure rate in the construction industry globally and in South Africa.

A mismatch with the construction managers hard and soft skills compared to the specific complexity of a project could lead to the ultimate failure of the project [12]. Williams (2002), cited by Mouchi *et al.* (2011) explains that project complexity is characterised by two measurements: structural complexity and uncertainty, as illustrated in Fig. 1 below.

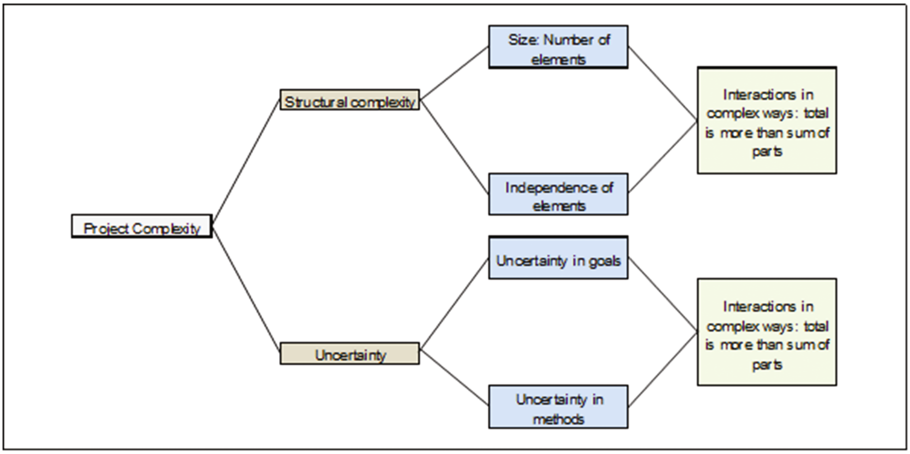

Fig. 1. Dimensions of project complexity [12].

Figure 1 further illustrates that structural complexity depends on a number of elements and objectivity of elements. Another measure which makes a project complex is the uncertainty in goals and methods. Therefore, if the construction manager needs to effectively manage on demanding construction projects he/she will require different approaches, mentality and skills.

According to Malvin (1979:36), a construction manager must command a skein of abilities that thread the range of human occupations. Melvin (1979) further elaborates and explains that the construction manager must have business management knowledge, understand the different facets of construction, interpret contractual aspects, sound knowledge of financial management, be able to take risks, mobilise people, equipment and be an educator. The construction manager needs this wide range of abilities to be able to take the architects' ideas and make it tacit [2]. Currently, the construction manager needs a wide range of skills to successfully manage or add value, to a project. The demand for experienced construction managers from industry will only increase. The pressing matter is that the skills gap is continuously increasing for various reasons. This is not only with regards to the South African construction industry, but a worldwide phenomenon [13–19].

The research results of Riley et al. (2008) [20] indicated an overemphasis on the development of technical skills and a need for more responsiveness to the development of emotional intelligence (EQ) [21]. The job of a construction manager greatly depends on their managerial skills, specifically soft skills [22].

According to Affandi (2012) the soft skills quality of construction management graduates has been an issue since around the 2000's [20]. The lack of non-technical soft skills and the high reliance on technical skills of graduates in the past have changed, concentrating more on human skills.

Human skills include the aptitude to work in teams, problem solving, adaptability and managerial skills (specifically social skills) [22]. Riley *et al*. (2008) stated that emotional intelligence and the related management and leadership skills can be learned and that the science behind leadership is a much more accurate predictor of success than any other form of measure [23]. According to Gorman (1998) cited by Riley *et al.* (2008), although emotional intelligence can be learned, it is not a technical skill that can be trained with a neocortical approach typically taken to develop analytical and technical abilities.

The tertiary institutions developed curriculums over years that focus heavily on the technical (hard skills) subjects that form part of the underlying fundamentals of a construction manager. The curriculums also emphasise some managerial and legal aspects with regards to the construction industry. These tertiary institutions in South Africa also differ in the weight of technical, managerial and legal subjects that are taught.

Managers use more of the hard skills (cognisable and easily measured) were as leaders focusses more on the soft skills (intangible and difficult to measure since they involve personal and subjective attributes) [24]. Hard skills will involve deliverables such as work breakdown structures, schedules and critical paths, etc. Most of the times there are software tools available that can assist in effectively managing these hard skills. In contrast with hard skills, soft skills cannot be linked with a deliverable or tangible output. Soft skills generally work without the use of tools or templates [25]. Hard skills may be meaningless if not supported by the managers' ability to combine the necessary soft skills [26]. Businesses rate employees' interpersonal skills more important than their analytical abilities [26].

There is an unyielding need for a new class of construction industry leaders. Construction managers are managers, but more importantly leaders [27, 28]. Badger *et al*. (2009) stated that there will be more construction activities in the next 30 years than what we had in the last 2000 years, where investment in talent and human resources will be unparalleled. People ensure construction projects' success and not processes and systems, thus reinforcing the idea of the importance of the human factor in the construction industry [29].

There is a broad consensus amongst academia and industry that graduates must be equipped with the necessary technical (hard) skills and non-technical (soft) skills. However, previous reports and research regarding new construction graduate employability indicates an unsatisfactory low level of soft skills [22, 29]. Abduwani (2012) stated that soft skills not only empower the higher education institutions and workforce in advancing career development and personal growth, they also create new opportunities and go beyond money motivation. Even in developed countries, there are serious shortages of recruits with the critical soft skills which companies require most. It is of utmost importance for policymakers and construction industry business leaders to develop interest and preserve talented construction managers to ensure long-term sustainable growth and competitiveness for the future of the industry as a whole [30].

2 Problem Statement

The demand for infrastructure and building programmes in a changing society is becoming more apparent. With the current widening gap in experienced skills, projects will become even more complex and eventually too demanding to maintain the successful management by construction site management professionals. The only way to ensure that the construction industry will keep up with what society is demanding, is to ensure that the industry selects the best students and retains them when they reach a higher level of competence.

The construction industry loses construction site managers after a few years of employment, resulting in a gap that cannot be filled overnight. Students who apply for studies in this industry and do not have the correct personality trait to work in construction site environments under stressful conditions will continuously increase the gap. Sometimes highly skilled construction site managers can be easily lured from the demands of construction site management to other industries for higher salaries, with better work conditions and work-life balance.

While the Baby Boomer generation slowly exiting the construction industry, taking with them their critical skills and leaving no replacements, a gap will be created that will be problematic to fill. Thus purpose fit candidates may have to be headhunted from as early as school level. They can then be presented with bursaries and a guarantee of work after their studies are completed to assist in creating a pool of purpose-fit candidates that are more likely to stay and grow in the industry.

3 Research Objectives

The aim of this research is to establish the core essential soft skills that a construction manager will need to cultivate to be able to manage future construction projects. According to Bilbo *et al.* (2000) the construction industry has become more dependent on accredited tertiary institutions to equip construction management students with relevant critical skills so that they can enter into the multifaceted and arduous work environment and add value to the construction industry. Theoretically it is acknowledged that significant improvements can be gained from improving the robustness of the quality of the soft skills inherited by students studying construction management. Through laying the foundation at these early stages, the young construction manager can accelerate quicker in becoming an effective leader in the construction industry.

The core objectives of this study can be divided as follows:

1. Determine if a construction site manager needs soft skills.
2. Determine the core soft skills needed for a construction site manager.

4 Research Method

Within this context, this research focussed on which of these soft skills overlap between the various different researches that's already completed. An in depth literature research was then conducted on each one of these identified soft skills that continuously overlap. A further literature study determined which skills and competencies a construction site manager needs, and is supported by empirical research. This data will then be used to assist in building a model that can assist in enhancing the probability of selecting a purpose fit student for the construction industry, which can secure a more sustainable pool with varied skill levels and competencies for industry to select from.

5 Results and Conclusions

In previous studies researchers supplied summaries of various lists that indicated the specific soft skills and competencies (using various sources) that a construction manager graduate need to obtain [10, 33]. Melvin (1979) has summarised a construction manager as someone who needs specific skills different from those seen in other professions. Melvin (1979) further indicated that for a construction manager to be successful he/she must be a chameleon. The construction manager must be a businessman, builder, lawyer, financier, army general, gambler and an educator [7].

This research area had received little attention in the past, as the construction industry is dominated by males and soft skills were seen as an indication of weakness. The majority of academic work focussed on the control of a program, lean construction, procurement, cost, quality and budgets.

As a construction project involves many incongruent views it was realised that Bono's "six thinking hats" can also be used at this stage to support these soft skills and see if they can fortify the idea of an increase in productivity, thus linking these soft skills with an increase in productivity [33]. The construction manager must have the ability to apply these soft skills and within using these softs skills manoeuvre between the six thinking hats. The construction managers' ability to use these interchangeable soft skills in combination or separate and float between the six thinking hats to make sound decisions, will increase his/her effectiveness on a construction site. As illustrated in Fig. 2, these interchangeable soft skills and six thinking hats can be used by the construction manager to transform into any single one or a combination of Melvin's professions. The construction managers' previous experience will also influence the level on which he/she can use Melvin's different professions effectively. The practical case studies indicated the possibility to add another profession to Melvin's already long list of professions. It is becoming very important for construction enterprises to understand the impact of the construction processes on the environment. Whether the construction enterprise outsource this function for complex projects or absorb it in-house for less complex projects, the construction manager must ultimately execute and manage around all the environmental issues specific to his/her site. It impacts from the costing perspective, managing the Environmental Management Plan during construction to carrying the risk of possible penalties that could be occurred.

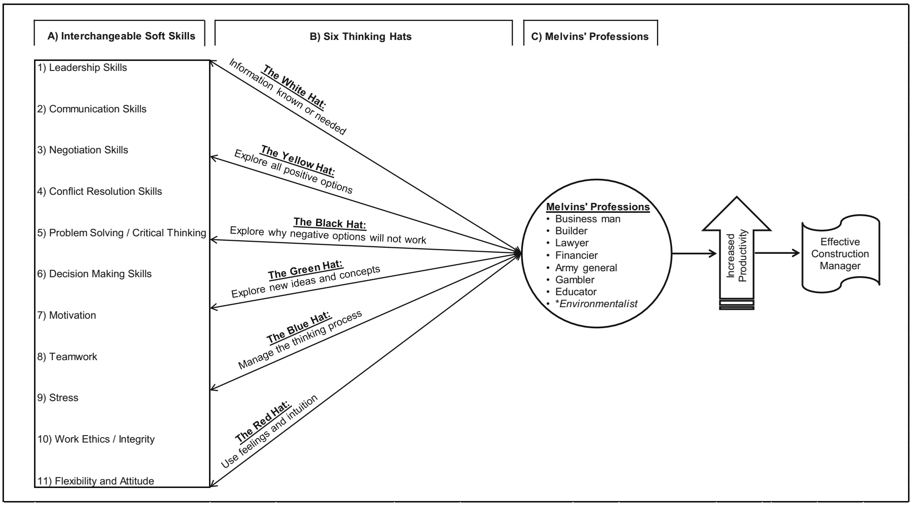

Fig. 2. The complex soft skills interaction model [7, 10, 32, 33].

This literature section sought to provide important and useful recommendations. Firstly, it indicated the importance of cultivating soft skills in a construction manager. Secondly, it emphasised the importance of the ability of the construction manager to apply these softs skills interchangeably in combination with the six thinking hats. Thirdly, the level of ease with which the construction manager can balance everything will depend on how effective he/she will be on the project. Fourthly, the margin of increase of production will be partially depended on the construction managers' level of effectiveness. Fifthly, to understand that a proper tertiary education in construction management and vast practical experience is critical, but that these soft skills are crucial in a supportive context to the latter. Lastly, that it is needed to try and find personal traits in individuals that typically inherit these soft skills.

6 Recommendations

From the above review of the literature, it can be seen that currently there are challenges that makes it even more crucial to select and retain these successful construction site managers with the purpose fit skills, abilities and personal profiles. This need for training and retaining construction managers is due to the:

- expanding opportunities in Africa
- the pivotal role the construction site manager interprets in the success of delivering projects
- large percentage of experienced construction site managers that is close to retirement

- the decrease of enrollments of new entrants into construction management tertiary institutions
- the major economic impacts of projects that failed
- the increase of the complexity of projects.

References

1. Watanabe, T., Sumpuwejakul, P.: A fundamental study on leadership styles of construction site managers on public construction projects in Thailand. J. SCE **9**, 227–235 (2002)
2. Jackson, B.: Construction Management: Jump Start. Wiley, Indiana (2010)
3. Sherrat, F., Farrell, P.: Introduction to Construction Management. Routledge, New York (2015)
4. Griffith, A., Watson, P.: Construction Management: Practice and Principles. Palgrave Macmillan, New York (2004)
5. Construction Industry Development Board. http://www.cidb.org.co.za
6. Makhene, D., Thwala, W.D.: Skilled labour shortages in construction contractors: literature review. In: Post Graduate Conference on Construction Industry Development (2009)
7. Melvin, T.: Practical Psychology in Construction Management. Litton Educational Publishing, New York (1979)
8. Bonnstetter, B.J., Suiter, J.I., Widrick, R.J.: The Universal Language, DISC: A Reference Manual. Target Training International Ltd., Scottsdale (1993)
9. Swanepoel, B., Erasmus, B., van Wyk, M., Schenk, H.: South African Human Resource Management: Theory and Practice. Juta & Co (Ltd), Cape Town (2000)
10. Othman, A.A.E.: A study of the competency requirements of property development graduates to meet the qualifications of the South African construction industry. J. EDT **12**, 2–28 (2014)
11. Love, P.E.D., Haynes, N.S., Sohal, A.S., Chan, A.P.C., Tam, C.M.: Key construction management skills for future success (2002)
12. Mouchi, G., Rotimi, J.O., Ramachandra, T.: The skill sets required from managing complex construction projects. J. BEA **3**, 89–100 (2011)
13. Oyegoke, A.S., McDermott, P., Aouad, G., Cleary, M.: Skill competency development strategies by a contractor. In: Proceedings of the Institution of Civil Engineers, pp. 1–10, Salford, UK (2009)
14. Citizen. http://connect.citizen.co.za/2020/construction-made-cool/
15. SA Commercial Prop News. http://www.sacommercialpropnews.co.za/business-specialties/property-education-training/5748-south-afric-has-skills-shortages-in-the-built-environment.html
16. The Guardian. http://www.theguardian.com/business/2015/oct/14/skills-shortage-and-the-sunday-sector
17. Sunday Independent. http://www.iol.co.za/news/politics/skills-shortages-hit-jobs-plans-1696850
18. Construction Industry Development Board (2007). http://www.cidb.org.co.za
19. Construction Industry Development Board (2004). http://www.cidb.org.co.za
20. Riley, D.R., Horman, M.J., Messner, J.I.: Embedding leadership development in construction engineering and management education. J. Prof. Iss. Eng. Ed. Pr. **8**, 143–155 (2008)
21. Burger, M., Verster, J.J.P.: Project Management in the Built Environment: The need for Industry specific knowledge (2013)

22. Affandi, H.M., Hassan, F., Ismail, Z., Mustaffa Kamal, M.F.: Soft skills implementation in construction management program: a survey of Malaysian public universities. In: IEEE Symposium on Humanities, Science and Engineering Research, pp. 767–772. IEEE Press, Kuala Lumpur (2012)
23. Ostadalimakhmalbat, M., Simmons, D.S.: Curricular and non-curricular factors impacting development of leadership competencies in undergraduate civil and construction students. In: ASEE American Society for Engineering Education, pp. 1–10. ASEE, Seattle (2015)
24. Abduwani, T.A.R.: The value and development of soft skills: the case of Oman. JITMB ARF **2**, 77–86 (2012)
25. Balancing Project Management Hard Skills and Soft Skills. http://projectmgmt.brandeis.edu/downloads/BRU_MSMPP_WP_Feb2012_
26. Robles, M.M.: Executive perception of the top 10 soft skills needed in today's workplace: buisiness and profesional quarterly. J. SAGE **75**, 453–465 (2012)
27. Badger, W., Sullivan, K., Wiezel, A., Bopp, P.H.: Profiling the leadership of project managers. IJCER **5**, 121–146 (2009)
28. Bradley, A., Hyatt, P.E., LEED, A.P.: Leadership development in undergraduate construction management curriculum. In: 49th ASC Annual International Conference Proceedings, ASC, California (2013)
29. Mahhasneh, J.K., Professor, W.T.: Rethinking construction curriculum: a descriptive cause analysis for soft skills gap among construction graduates. In: 51th ASC Annual International Conference Proceedings, ASC, Virginia (2015)
30. McKeon, J.J.: Becoming a Construction Manager: A Guide to Careers in Construction. Wiley, New York (2011)
31. Bilbo, D., Fetters, T., Burt, R., Avant, J.: A study of the supply and demand for construction education graduates. JEDT **4**, 54–65 (2000)
32. Sheth, M.: Six thinking hats. AJMR **2**, 814–820 (2012)
33. The construction manager leading characteristics for the success of construction projects in the Gaza Strip. http://library.iugaza.edu.ps/thesis/104194.pdf

Musculoskeletal Aspects of Social and Occupational Ergonomics

Upper Limb Repetitive Movement Risk Assessment by Means of sEMG Parameters

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Abstract. The aim of the study was to provide a biomechanical risk assessment in a mechanical engineering industry using sEMG fatigue parameters. Two experienced right-handed workers were enrolled for the study. sEMG signals were recorded bilaterally from the following upper limb muscles: middle Trapezius, anterior Deltoid, lateral Deltoid and long head of Biceps Brachii. The envelopes of the activity of each muscle were computed as a percentage of the Maximal Voluntary Contraction (%MVC). We also computed Root Mean Square (RMS) and Median Frequency (MDF) to investigate localized muscle fatigue. For the studied workstations, right muscles were more involved than left ones and consequently by means of JASA fatigue plot we observed more fatigue events in the right than in the left upper limb in both workers. Results showed different muscular behavior for each workstation and specific motor patterns. Despite the fact that the mean cycle activity failed to exceed 10% of MVC, activity peaks frequently reached up to 30% of MCV. These short-term peak values could be the cause of increased biomechanical risk. By studying sEMG fatigue parameters, it is possible to obtain a more detailed risk assessment and to provide insight towards workstation improvements.

Keywords: Joint analysis of the spectrum and amplitude · Localized muscle fatigue · Biomechanical risk assessment · MSDs

1 Introduction

The data presented last year by the President of INAIL (Italian Workers' Compensation Authority) to the Italian Parliament demonstrates that, in Italy, the reports of occupational illness caused by Musculoskeletal Disorders (MSDs) have increased continuously since 2011, in both absolute terms and percentage terms [1]. The most recent data shows that MSDs represent, with 37,240 reports in 2015, 63.2% of all occupational illnesses reported to the Institute. Similar MSDs values have also been reported in the United States [2] and in the European Union [3, 4].

Various methods for assessing the risk of the biomechanical overloading of upper limbs are proposed in the literature, also reported in the ISO 11228-3 standard [5]. Each of these methods assesses different risk factors but it is difficult for them to manage all

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the features of the many types of work that can be encountered in industrial environments. However, although in different ways, all of the methods do seem to agree on the fact that, of all the risk factors taken into consideration, that which most influences overall risk is the 'strength' factor, defined in the ISO 11228-3 standard as the "*physical effort of the operator required to execute the task*".

With these methods, exertion is often quantified using scales of subjective perception, such as the Borg Scale [6], which presents many limitations.

In literature, several authors have tried to study the relationship between EMG and the Borg scale [7, 8] under isometric conditions, getting a certain degree of correlation.

There are also several studies that have already used Surface Electromyography (sEMG) to quantify muscular fatigue, under both static and dynamic conditions, in the laboratory and in the field [9–15].

The values that can be obtained in terms of average percentage of Maximum Voluntary Contraction (%MVC), within a typical mechanical engineering industry production cycle lasting between 40 and 60 s, are relatively low. Peak values within these production cycles are diluted as part of the mean %MVC and are not properly taken into consideration.

The aim of this study is to apply, in a real working situation, the Joint Analysis of the Spectrum and Amplitude (JASA) of sEMG [16–18], which analyzes the temporal changes in the amplitude of the sEMG signal, evaluated using the Root Mean Square (RMS) and the frequency of the sEMG signal, expressed as Median Frequency (MDF). By integrating the values of the angular coefficients of the regression lines of these two parameters, it is possible to obtain information regarding the physiological state of the muscle through division into four categories:

1) recovery (decrease in RMS and increase in MDF)
2) force decrease (decrease in RMS and decrease in MDF)
3) force increase (increase in RMS and increase in MDF)
4) fatigue (increase in RMS and decrease in MDF)

2 Materials and Methods

We evaluated two workstations (A and B) in a mechanical engineering industry that produces different pieces. We selected the line producing the heaviest one (weighing 5 kg). The two workstations differed in terms of the different contributions by the operator. In Workstation A, workers were less involved than in Workstation B due to an increased level of automation. Two skilled right-handed male workers were enrolled in the study. For each worker and for each workstation, we undertook data collection before the lunch break. Each data collection exercise involved the production of three pieces (three cycles); the job cycle was different for each of the three cycles since it was partially determined by the workers. However all the observed cycles were within the limit of 42 s, as suggested by the factory. Jammings occurred randomly during processing resulting in unscheduled breaks. However, during the data collection, there were no jammings in the production line or unusual worker activity. Neither of the participants had a history of trunk or upper limb musculoskeletal disorders and both were in very good health.

Bipolar sEMG was obtained during dynamic contractions with a sampling rate of 1000 Hz, using a 16-channel Wi-Fi transmission surface electromyograph (Free-EMG300 System, BTS, Milan, Italy). A pre-process filtering and denoising procedure was performed. After skin preparation, surface electromyographic signals were detected from each muscle by means of two Ag/AgCl pre-gelled disposable surface electrodes (H124SG, Kendall ARBO, Donau, Germany), which had a detection surface of 10 mm. Electrodes were placed in the direction of the muscle fibers, according to the Atlas of Muscle Innervation Zones recommendations [19].

We investigated bilaterally the following muscles of the upper limb: Middle Trapezius (TRAPsx, TRAPdx; left and right respectively), Deltoid Anterior (DAsx, DAdx; left and right respectively), Deltoid Lateral (DLsx, DLdx; left and right respectively) and Long Head of Biceps Brachii (BICsx, BICdx; left and right respectively).

For each muscle, muscle activity was computed as a percentage of maximal voluntary contraction (%MVC). In order to elicit the MVC from each muscle, six isometric exertions were performed according to SENIAM recommendations [20, 21]. Collected data was processed by means of Analyzer software (Smart Analyzer, BTS, Milan, Italy). The sEMG signals were rectified, integrated with a mobile window of 0.125 s, filtered with a 5 Hz Hamming low-pass filter and normalized to the maximum MVC value according to SENIAM recommendations; sEMG signals of MVC were computed using the same procedure.

The sEMG signals acquired were also processed by means of Analyzer software to compute the fatigue index. The lower and upper cut-off frequencies of the Hamming filter were 10 Hz and 400 Hz, respectively, and the common mode reaction ratio was 100 dB. Fatigue indices were calculated for each signal by dividing the signal into 500 ms epochs, within which amplitude and frequency parameters were computed. Since these parameters have demonstrated a linear trend [22], the linear regression was evaluated and then the data was normalized with respect to the y-axis.

3 Results

Whilst observed differences in muscular behavior, it was possible to identify, for each muscle, characteristic activity patterns, which were used to define the cycle start and end and to normalize the cycle durations.

Workstation A displayed significant activation values only for the right upper limb. A primary cluster of BICdx and DLdx activity, between 5% and 20% of the cycle, showed activation levels of about 15% of MVC for the BICdx and about 20% of MVC for the DLdx. Within the cycle, this initial stage presented the highest activation values. The BICdx and DLdx were also activated to a significant degree between 21% and 50% of the cycle and between 71% and 90% of the cycle. In both these stages, the level of activity was around 10% of MVC for the BICdx and 15% of MVC for the DLdx. The analyzed muscles of the left limb did not show significant overall levels of activation.

Workstation B also displayed a primary cluster of activity between 5% and 20% of the cycle. This involved, in particular, both Trapezia and the BICsx, with activity of about 15% of MVC, and the DAdx with activity of about 30% of MVC.

Between 20% and 50% of the cycle, activity was reduced in all the muscles under analysis.

A significant increase in activity was observed between 51% and 60% of the cycle. In this stage, for both the Trapezia and both the Anterior Deltoids, values of about 20% of MVC were observed, whilst the bicep activity was slightly higher (25% of MVC).

Another significant stage of activity involving all the muscles was observed between 65% and 75% of the cycle. Activation values in this stage were found to be 30% of MVC for the TRAPdx, DAdx and BICdx, 25% of MVC for the DAsx and 20% of MVC for the DLdx, DLsx, TRAPsx and BICsx.

Tables 1 and 2 display the results described above in relation to levels of activation expressed as %MVC.

Table 1. Summary, for each of the cycle stages identified for Workstation A, of the muscles most involved and respective level of activation expressed as %MVC.

Cycle time percentage and level of muscle activation (%MVC)				
5–20%	21–50%	51–70%	71–90%	91–100%
BICdx 15%	BICdx 10%	Negligible activity	BICdx 10%	Negligible activity
DLdx 20%	DLdx 15%		DLdx 15%	

Table 2. Summary, for each of the cycle stages identified for Workstation B, of the muscles most involved and respective level of activation expressed as %MVC.

Cycle time percentage and level of muscle activation (%MVC)				
5–20%	21–50%	51–60%	61–75%	76–100%
	Negligible activity		DAsx 25%	Negligible activity
		TRAPsx 20%	DLsx 20%	
TRAPsx 15%		DAsx 20%	TRAPsx 20%	
BICsx 15%		BICsx 25%	BICsx 20%	
TRAPdx 15%		TRAPdx 15%	TRAPdx 30%	
DAdx 30%		DAdx 20%	DAdx 30%	
		BICdx 25%	BICdx 30%	
			DLdx 20%	

Table 3. RMS and MDF regression coefficients and JASA interpretation for each muscle of the first operator and for the two investigated workstations (A and B)

Muscle	RMS A	MDF A	JASA A	RMS B	MDF B	JASA B
DAsx	0,0015	0	NC	–0,0007	–0,0005	force decr.
DLsx	–0,0013	–0,0008	force decr.	–0,0023	–0,0001	force decr.
BICsx	–0,0002	0,0008	recovery	–0,0002	0,0003	recovery
TRAPsx	0,0009	0,0011	force incr.	–0,0005	0,0003	recovery
DAdx	–0,0017	–0,0001	force decr.	0,0025	0,001	force incr.
DLdx	0,008	0,0003	force incr.	0,0053	–0,0008	fatigue
BICdx	–0,0011	–0,0013	force decr.	0,0055	–0,0019	fatigue
TRAPdx	–0,0015	0,0011	recovery	0,0022	–0,0004	fatigue

Table 4. RMS and MDF regression coefficients and JASA interpretation for each muscle of the second operator and for the two investigated workstations (A and B)

Muscle	RMS A	MDF A	JASA A	RMS B	MDF B	JASA B
DAsx	0,0006	0,0004	force incr.	–0,0005	0,0005	recovery
DLsx	–0,0011	–0,0001	force decr.	–0,0017	–0,001	force decr.
BICsx	0,0005	–0,0009	fatigue	–0,001	0,0008	recovery
TRAPsx	–0,0006	–0,0003	force decr.	–0,0001	0,0009	recovery
DAdx	0,0006	–0,0004	fatigue	–0,0031	0	NC
DLdx	0,0006	0,0002	force incr.	–0,002	–0,0009	force decr.
BICdx	0	–0,0004	NC	0,0024	–0,0011	fatigue
TRAPdx	0,0068	–0,0003	fatigue	0,0036	–0,0006	fatigue

Tables 3 and 4 below provide a summary of the angular coefficients of the linear regression obtained for the two parameters under investigation (RMS and MDF) and the respective JASA classification for the two operators investigated, for each of the eight muscles investigated.

Figures 1 and 2 below show JASA plots of the results of Tables 3 and 4. In Fig. 1 displays a Cartesian diagram of the distribution of events, for both operators and both workstations, for the left upper limb. Figure 2 shows the distribution of events, for both operators and both workstations, of the right upper limb.

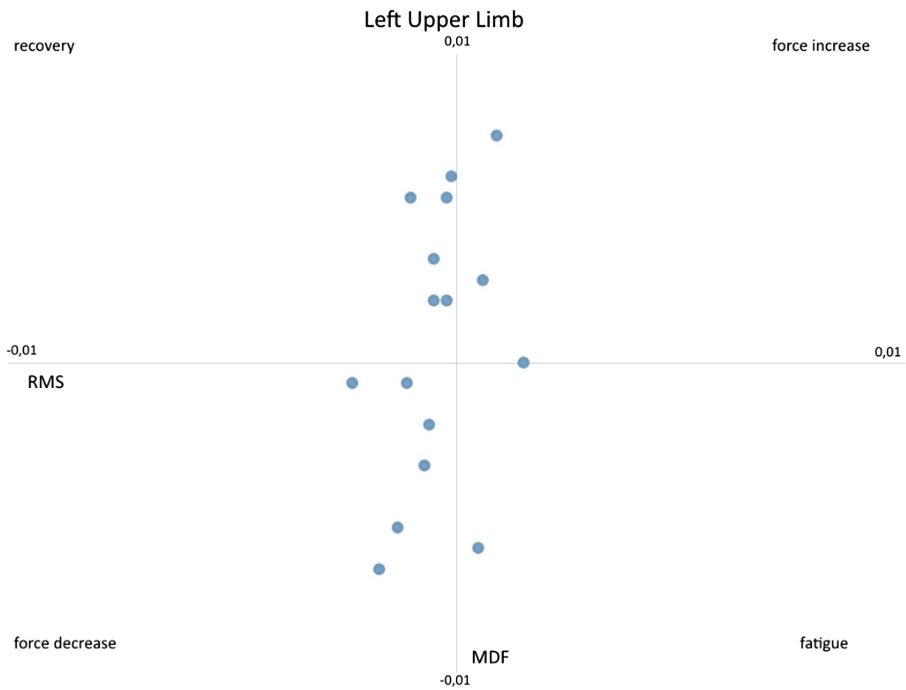

Fig. 1. JASA plot of the left upper limb muscles, for both operators and both workstations

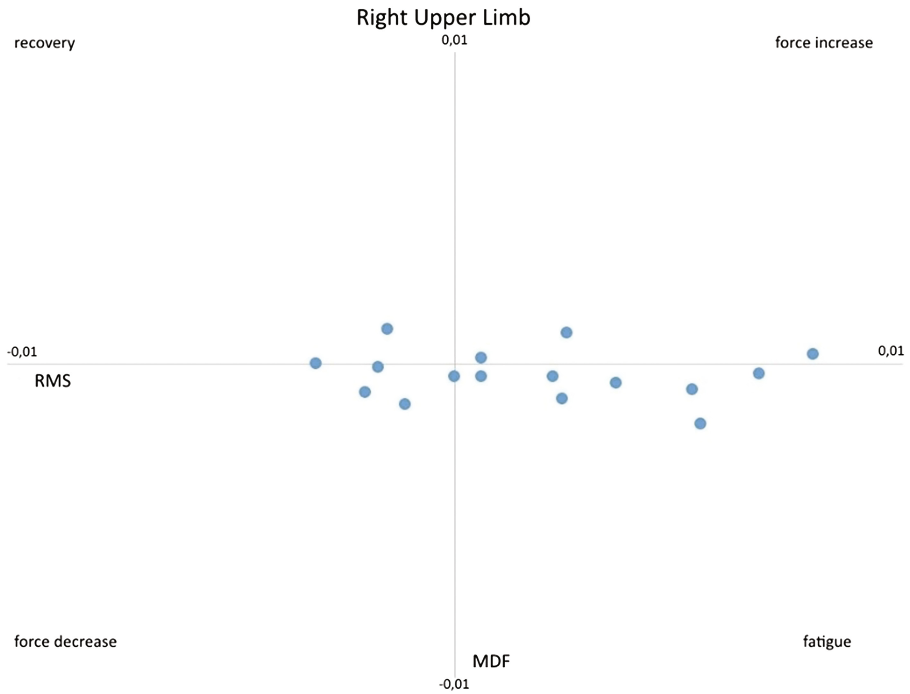

Fig. 2. JASA plot of the right upper limb muscles, for both operators and both workstations

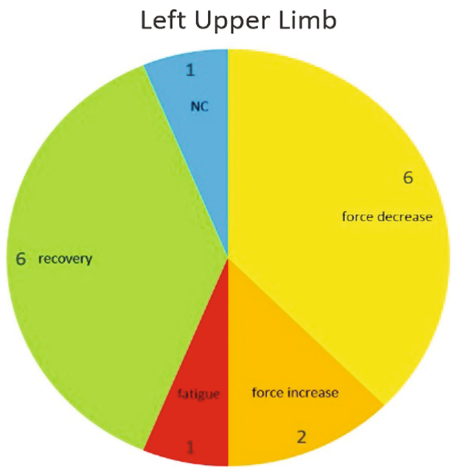

Fig. 3. Image showing the number of events for the left upper limb in the four JASA quadrants, for both workstations and both operators. Not Classifiable (NC) events are also represented

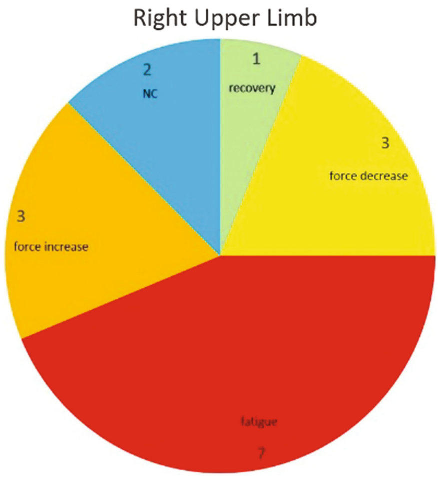

Fig. 4. Image showing the number of events for the right upper limb in the four JASA quadrants, for both workstations and both workers. Not Classifiable (NC) events are also represented

The pie charts of the figures, shown below, display the number of events observed in the four quadrants of the JASA plot for the left upper limb (Fig. 3) and the right upper limb (Fig. 4). Of the overall 32 events analyzed (16 per side), three could not be classified (NC) due to the angular coefficient of either the RMS (one event) or MDF (two events) being of zero value. With regard to the 16 events of the chart of the left upper limb, the greatest number of events was observed in the quadrants ‘recovery’ and ‘force decrease’ (6 in each). In addition, three events were observed in the ‘force increase’ quadrant and one in the ‘fatigue’ quadrant.

However, with regard to the 16 events on the right-hand side (Fig. 4), the quadrant with the greatest number of events was the ‘fatigue’ quadrant (seven events). In addition, three events were observed in the ‘force increase’ and ‘force decrease’ quadrant and only one in the ‘recovery’ quadrant.

4 Discussion

For each investigated muscle and for each workstation, characteristic motor activity was identified, making easy to identify start and end of the three cycles. The results demonstrate that, in the analysis of the two operators at the two workstations, the most involved muscles in Workstation A were the DLdx (15–20% of MVC) and the BICdx (10–15% of MVC). In Workstation B, however, all investigated muscles were involved on both sides. In particular, in Workstation B, there proved to be most use in the stage between 61% and 75% of the cycle of the TRAPdx (30% of MVC), DAdx (30% of MVC), BICdx (30% of MVC) and the DAsx (25% of MVC). This stage corresponds to the part of the work cycle that required the most effort, in which the operator had to remove the component being processed (weight 5 kg) from the container, at waist height, lift it to shoulder height and turn it over.

As far as concerns the results obtained from the JASA analysis, despite the fact that the data was collected under dynamic conditions and not under static conditions, as recommended by Merletti [23], a considerable number of events were observed in the 'fatigue' quadrant for the right upper limb, as illustrated in Fig. 4.

The results proved more conflicting for the left upper limb, however, which, especially for Workstation A, was used less and with much lower activation values.

It was not possible to carry out further, more representative data collection, due to the limited time we were awarded by the company to undertake our study.

The results we obtained demonstrate that sEMG proves to be, to date, a technology capable of providing useful indications for biomechanical risk assessment, including in actual work conditions and we can conclude that our results confirm that stated by Cirfrek [24] in his review: "*….the future of this methodology (sEMG) is projected by estimating those methods that have the greatest chance to be routinely used as reliable muscle fatigue measures….*".

In any case, research on broader samples of the working population is necessary in order to verify the effectiveness of JASA under dynamic conditions within real manufacturing situations.

References

1. INAIL Relazione annuale 2015 del Presidente. Appendice statistica. Rome 22 June (2016). https://www.inail.it/cs/internet/docs/allegato_relazione_del_presidente_appendice_statistica_2015pdf.pdf, Accessed 28 Jan 2017
2. Bureau of Labor Statistics: Nonfatal occupational injuries and illnesses requiring days away from work, 2011. US Department of Labor, Washington (DC) (2012)
3. Schneider, E., Irastorza, X.: OSH in figures: work-related musculoskeletal disorders in the EU-Facts and figures. In: European Agency for Safety and Health at Work Luxembourg, May 4 (2010)
4. Silva, A., Steinbuka, I.: Health and Safety at Work in Europe (1999-2007): A Statistical Portrait. Eurostat, Belgium (2010)
5. ISO 11228-3 Ergonomics – Manual handling – Part 3: handling of low loads at high frequency (2007)
6. Borg, G.A.V.: A category scale with ratio properties for intermodal and interindividual comparison. In: Geissler, H.G., Petzold, P. (eds.) Psychophysical Judgement and the Process of Perception, pp. 25–34 (1982)
7. Hummel, A., Läubli, T., Pozzo, M., Schenk, P., Spillmann, S., Klipstein, A.: Relationship between perceived exertion and mean power frequency of the EMG signal from the upper trapezius muscle during isometric shoulder elevation. Eur. J. Appl. Physiol. **95**(4), 321–326 (2005)
8. Troiano, A., Naddeo, F., Sosso, E., Camarota, G., Merletti, R., Mesin, L.: Assessment of force and fatigue in isometric contractions of the upper trapezius muscle by surface EMG signal and perceived exertion scale. Gait Posture. **28**(2), 179–186 (2008)
9. Chaffin, D.B.: Localized muscle fatigue definition and measurement. J. Occup. Med. **15**(4), 346–354 (1973)

10. Wiker, S.F., Chaffin, D.B., Langolf, G.D.: Shoulder posture and localized muscle fatigue and discomfort. Ergonomics **32**(2), 211–237 (1989)
11. Bonato, P., Roy, S.H., Knaflitz, M., De Luca, C.J.: Time-frequency parameters of the surface myoelectric signal for assessing muscle fatigue during cyclic dynamic contractions. IEEE Trans. Biomed. Eng. **48**(7), 745–753 (2001)
12. Lin, M.I., Liang, H.W., Lin, K.H., Hwang, Y.H.: Electromyographical assessment on muscular fatigue: an elaboration upon repetitive typing activity. J. Electromyogr. Kinesiol. **14**(6), 661–669 (2004)
13. Hostens, I., Ramon, H.: Assessment of muscle fatigue in low-level monotonous task performance during car driving. J. Electromyogr. Kinesiol. **15**(3), 266–274 (2005)
14. Bosch, T., De Looze, M., Van Dieen, J.: Development of fatigue and discomfort in the upper trapezius muscle during light manual work. Ergonomics **50**(2), 161–177 (2007)
15. Mahdavi, N., Motamedzade, M., Jamshidi, A.A., Darvishi, E., Moghimbeygi, A., Heidari Moghadam, R.: Upper trapezius fatigue in carpet weaving: the impact of a repetitive task cycle. Int. J. Occup. Saf. Ergon. **6**, 1–11 (2016)
16. Luttmann, A., Sökeland, J., Laurig, W.: Electromyographical study on surgeons in urology. I. influence of the operating technique on muscular strain. Ergonomics **39**(2), 285–297 (1996)
17. Luttmann, A., Jäger, M., Sökeland, J., Laurig, W.: Electromyographical study on surgeons in urology. II. determination of muscular fatigue. Ergonomics. **39**(2), 298–313 (1996)
18. Hägg, G.M., Luttmann, A., Jäger, M.: Methodologies for evaluating electromyographic field data in ergonomics. J. Electromyogr. Kinesiol. **10**(5), 301–312 (2000)
19. Barbero, M., Merletti, R., Rainoldi A.: Atlas of muscle innervation zones. Springer, Italia (2012). ISBN 978-88-470-2462-5
20. Hermens, H.J., Freriks, B., Disselhorst-Klug, C., Rau, G.: Development of recommendations for SEMG sensors and sensor placement procedures. J. Electromyogr. Kinesiol. **10**(5), 361–374 (2000)
21. Hermes, H., Freriks, B., Merletti, R., et al.: European recommendations for surface ElectroMyoGraphy (SENIAM). CLUT (2000)
22. Dimitrova, N.A., Dimitrov, G.V.: Interpretation of EMG changes with fatigue: facts, pitfalls, and fallacies. J. Electromyogr. Kinesiol. **13**(1), 13–36 (2003)
23. Merletti, R., Farina, D.: Surface Electromyography: Physiology, Engineering and Applications. In: Surface EMG in Ergonomics and Occupational Medicine, Chap. 13. Biomedical Engineering, 1st edn. IEEE Press (2016)
24. Cifrek, M., Medved, V., Tonković, S., Ostojić, S.: Surface EMG-based muscle fatigue evaluation in biomechanics. Clin. Biomech. **24**(4), 327–340 (2009)

The Impact of Ergonomic Exposures on the Occurrence of Back Pain or Discomfort: Results from the First Working Conditions Survey in Quito-Ecuador

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Abstract. This article determines the prevalence of back pain or discomfort in the working population of Quito, the capital city of Ecuador, and examines its association with ergonomic exposures. A cross-sectional study based on data from the First Working Conditions Survey of Quito-Ecuador (364 women and 377 men) was performed. Overall, 56% of women and 43.5% of men reported back pain. Moreover, a gradient from upper to lower job categories was found for both sexes, especially among women. Among both sexes, back pain and discomfort were significantly associated with awkward, manual handling, repetitive movements and prolonged sitting or standing. The strongest associations were found among women. Therefore, monitoring ergonomic exposures and developing special programs for addressing back disorders are needed.

Keywords: Prevalence · Musculoskeletal disorders · Human engineering · Health surveys · Ecuador · Public health surveillance

1 Introduction

Back pain is prevalent among the working population worldwide and it is an important cause of disability and loss of working days. According to the 2005 European Working Survey (EWCS), 24.7% of the workers in the 27 member states of the European Union (UE-27) reported back pain [1]. In less economically developed countries data is scarce, however, a recent cross-sectional study based on 12 024 workers from the 2011 First Central American Survey of Working Conditions and Health (ECCTS, by its Spanish acronym), found that almost half of the working population reported having back pain in the previous 4 weeks [2]. On the other hand, it was estimated that low back pain arising from ergonomic exposures caused 21.7 million disability-adjusted life years (DALYs) worldwide, in 2010 [3].

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The effects of ergonomic risk factors on the occurrence of back pain in the working population have been studied extensively, especially in economically developed countries. Several studies have found evidence of an increased risk of low back pain for workers exposed to manual handling and awkward postures (flexion and rotation of the trunk) [4–6]. Further, there is also some evidence about the impact of prolonged standing on back pain [7].

The exposure to ergonomic risk factors has been found to be one of the most frequent for the working population among several countries [8–11]. However, currently there is no available information about the prevalence of back pain and its association with ergonomic exposures on the Ecuadorian working population. Recently, Quito, the capital city of Ecuador developed its First Working Conditions Survey (I ECSST) [12], which allows studying multiple variables on work and health including back pain or discomfort and several ergonomic risk factors.

The objectives of this study were: (i) to determine the prevalence of back pain or discomfort in the working population of Quito, the capital city of Ecuador and (ii) to examine the association between back pain or discomfort and ergonomic exposures.

2 Methods

2.1 Data Source

Data was taken from the First Survey on Safety and Health of Quito (I ECSST, by its Spanish acronym), the capital city of Ecuador, conducted in 2016. The I ECSST is a cross-sectional survey based on a representative sample of salaried workers insured by social security, aged 18 or older, from all sectors of economic activity, and residing in Quito. In this survey, sample selection followed a multistage stratified random sampling procedure. A sample of 741 workers was drawn from the projected population in 2015 based on the 2010 Ecuadorian Population and Housing Census. Trained interviewers administered the questionnaires in a face-to-face interview at the respondent's home between April and July 2016. Details of the survey are reported elsewhere [12].

2.2 Variables

Ergonomic Exposures. We examined five ergonomic exposures, including awkward postures, manual handling, repetitive movements and prolonged sitting or standing. For the first two variables, workers were asked: (i) "During your working day, do you perform tasks requiring awkward postures? (always, very often, sometimes, almost never and never)" and (ii) "During your working day, do you lift, move or carry animals or other heavy loads? (always, very often, sometimes, almost never and never)". The categories "always" or "very often" defined workers as being exposed. Repetitive movements, was determined by asking workers whether they perform repetitive movements in short periods of time, in a working day (yes/no). Prolonged sitting or standing was elicited by asking respondents to describe their usual work posture.

Back Pain or Discomfort. Data on back pain or discomfort was obtained by asking the respondents: "In the past month, have you had discomfort or pain in the back? (yes or no)."

Covariates. Analyses were adjusted for age (categorized into 18–34 years, 35 to 49 years, and more than 49 years) and job category. Job category was coded into three categories according to the nine original broad categories of the International Standard Classification of Occupations (ISCO): (i) upper (managers and professionals), (ii) medium (technicians and associate professionals, clerks, and service workers and shop and market sales workers), and (iii) lower (skilled agricultural and fishery workers, craft and related trades workers, plant and machine operators and assemblers, and elementary occupations).

2.3 Data Analysis

First, descriptive statistics were calculated for sociodemographic and labor characteristics, ergonomic exposures and back pain or discomfort.

Second, the prevalence of back pain or discomfort was calculated by age groups (18–34, 35–49 and ≥ 50 years), job category (upper, medium and lower), weekly working hours (≤ 40 and ≥ 41 h), and ergonomic exposures (awkward postures, manual handling, repetitive movements and prolonged sitting or standing).

Third, multiple logistic regression adjusted for age and job category were fitted in order to test the association between ergonomic exposures and back pain or discomfort. All the analyses were separated by sex. Analyses were conducted using Stats V.11.

3 Results

3.1 General Description of the Sample

A total of 741 workers (364 women and 377 men) were analyzed (Table 1). Most of the working population were young, with 87.1% of women and 80.9% of men under 50 years of age. Both women and men worked mainly in the service sector (90.1% and 83.8%, respectively), and most of them occupied medium job categories (63.5% of women and 56.2% of men). Regarding ergonomic exposures, more than 60% of all respondents said they were exposed to repetitive movements always or very often. This was followed by 30.2% of women and 22.6% of men reporting exposure to prolonged sitting or standing, 10.2% of women and 20.4% of men indicating exposure to manual handling, and 12.6% of women and 14% of men reporting being exposed to awkward postures. In regard to back pain or discomfort, almost half of the working population (56% of women and 43.5% of men) stated that they had experienced pain in the four weeks before the survey.

Table 1. General description of the population sample by sex, in Quito, 2016.

Characteristics	Women		Men		Total	
	n	%	n	%	n	%
Age groups						
18–34	168	46.2	146	38.7	314	42.4
35–49	149	40.9	159	42.2	308	41.6
≥ 50	47	12.9	72	19.1	119	16.1
Economic activity						
Agriculture, mining and quarrying	3	0.8	8	2.1	11	1.5
Industry	23	6.3	37	9.8	60	8.1
Construction	10	2.8	16	4.2	26	3.5
Services	328	90.1	316	83.8	644	86.9
Job category						
Lower	81	22.3	112	29.7	193	26.1
Medium	231	63.5	212	56.2	443	59.8
Upper	52	14.3	53	14.1	105	14.2
Weekly working hours (mean (SD))	40.6 (7.1)		42.4 (8.5)		41.6 (7.9)	
Ergonomic exposures						
Awkward postures	46	12.6	55	14.6	101	13.6
Manual handling	37	10.2	77	20.4	114	15.4
Repetitive movements	215	60.2	241	65.0	456	62.6
Prolonged sitting or standing	110	30.2	85	22.6	195	26.3
Back pain or discomfort	204	56.0	164	43.5	368	49.7

Salaried workers aged over 18 years, covered by social security.

3.2 Prevalence of Back Pain or Discomfort

According to the studied age groups, the prevalence of back pain in women was higher among workers aged over 49 years and in men among those aged 18 to 34 years old. Among the whole working population, women in lower job categories were more likely to report back pain or discomfort (70.4%). Specifically for ergonomic exposures, the prevalence of back pain or discomfort for both men and women was highest among those exposed to awkward postures (89.1% of women and 69.1% of men) (Table 2).

3.3 Associations of Ergonomic Exposures with Back Pain or Discomfort

For both women and men, being exposed to any of the ergonomic risk factors was significantly associated with back pain or discomfort (Table 3). The magnitude of the associations was much higher among women. The strongest association occurred between awkward postures and back pain or discomfort among men (aOR = 3.3, 95% CI = 1.7–6.1) and, especially, among women (aOR = 6.9, 95% CI = 2.6–18.2).

Table 2. Number (n) and prevalence (%) of back pain or discomfort according to sociodemographic and labor characteristics, and ergonomic exposures by sex, in Quito, 2016.

	Women			Men			Total		
	n	%	(95% CI)	n	%	95% CI	n	%	95% CI
Age groups									
18–34	96	57.1	(49.6–64.7)	67	45.9	(37.8–54.0)	163	51.9	(46.4–57.5)
35–49	78	52.4	(44.3–60.4)	66	41.5	(33.8–49.2)	144	46.8	(41.2–52.3)
≥ 50	30	63.8	(49.9–77.8)	31	43.1	(31.5–54.6)	61	51.3	(42.2–60.3)
Job categories									
Lower	57	70.4	(60.3–80.4)	55	49.1	(39.8–58.4)	112	58.0	(51.0–65.0)
Medium	124	53.7	(47.2–60.2)	94	44.3	(37.6–51.1)	218	49.2	(44.5–53.9)
Upper	23	44.2	(30.6–57.9)	15	28.3	(16.0–40.6)	38	36.2	(36.2–45.4)
Ergonomic exposures									
Awkward postures	41	89.1	(80.0–98.3)	38	69.1	(56.7–81.5)	79	78.2	(70,1–86,3)
Manual handling	29	78.4	(64.9–91.9)	46	59.7	(48.7–70.8)	75	65.8	(57.0–74.6)
Repetitive movements	136	63.3	(56.8–69.7)	119	49.4	(43.0–55.7)	255	55.9	(51.4–60.5)
Prolonged sitting or standing	75	68.2	(59.4–76.9)	46	54.1	(43.4–64.8)	121	62.1	(41.1–49.4)

Salaried workers aged over 18 years, covered by social security.

Table 3. Associations (odds ratios) between ergonomic exposures and back pain or discomfort by sex in Quito, 2016.

	Women				Men			
	OR	(95% CI)	aOR	(95% CI)	OR	(95% CI)	aOR	(95% CI)
Awkward postures								
No	1		1		1		1	
Yes	7,8	(3,0–20,4)***	6,9	(2,6–18,2)***	3,5	(1,9–6,4)***	3,3	(1,7–6,1)***
Manual handling								
No	1		1		1		1	
Yes	3,1	(1,4–7,1)**	2,7	(1,2–6,3)*	2,3	(1,4–3,8)**	2,1	(1,3–3,7)**
Repetitive movements								
No	1		1		1		1	
Yes	2,2	(1,4–3,3)***	2,1	(1,4–3,3)**	1,9	(1,2–2,9)**	1,9	(1,2–2,9)**
Prolonged sitting or standing								
No	1		1		1		1	
Yes	2,1	(1,3–3,3)*	1,9	(1,2–3,1)*	1,7	(1,1–2,7)*	1,6	(1,1–2,6)

Salaried workers aged over 18 years, covered by social security.
OR odds ratio; 95% confidence interval, aOR adjusted odds ratio for age and job category
*p < 0.05, **p < 0.01, ***p < 0.001

4 Discussion

To our knowledge, this is the first time that a sample of workers of different economic sectors from the capital city of Ecuador has been used to study ergonomic exposures and back pain or discomfort. The study has produced three main findings: (i) Back pain or discomfort was prevalent among the formal working population in Quito, especially among women occupied in lower job categories. (ii) The most frequent ergonomic exposure for both men and women was the exposure to repetitive movements, followed by prolonged sitting or standing, especially among women; and manual handling, particularly among men; and (iii) all ergonomic exposures were associated with back pain or discomfort, however these associations were stronger among women.

Our results are consistent with previous studies, which have shown that back pain is very frequent among the working population worldwide. In fact, a study based on the ECCTS, found that the prevalence of back pain in workers was over 50%. However, it should be noted that the prevalence in our study is higher than in Panama and lower than in Nicaragua (29.1% and 71.5%, respectively) [13]. Moreover, this prevalence is much higher than in the 27 member states of the EU-27 (27.4%), according to data from the 2005 EWCS [10].

Gender differences, with more women than men reporting back pain, coincide with previous studies [14]. These differences could be explained by a greater pain sensitivity in women compared to men, as has been found in previous studies [15]. Nevertheless, other studies have shown that among women, work-family conflict plays a significant role in the occurrence of back pain [16]. Future studies are needed to assess this hypothesis. As expected, workers from lower job categories reported back pain more frequently, which is consistent with previous studies [17]. These inequalities have been attributed to differences in physical and psychosocial working conditions, as well as lifestyle factors [18]. Therefore, the interaction of household labor and job category, as a proxy of social class, might be having a negative impact on women's health [19].

The frequency of exposure to ergonomic risk factors in the working population of Quito follows a similar pattern than in other working populations. For example, according to the 2006 Korean Working Conditions Survey [8], the 2011 Spanish Working Conditions Survey [9], and the 2010 European Working Conditions Survey (EWCS) [10] repetitive movements was the most prevalent exposure among their workers. In addition, according to the EWCS, manual handling was very frequent in the UE-27. Recently, similar results were found in a study which used a sample of 15 241 workers from the working conditions surveys available in different Latin American countries [11]. This study found that repetitive movements and manual handling were among the most frequent exposures in Colombia, Argentina, Central America and Uruguay. On the other hand, differences of exposure between sexes might be explained by the horizontal segregation of the labor market, were women and men are concentrated in different economic activities, occupations or tasks [20].

As in our study, previous research has shown the association between awkward postures, manual handling, repetitive movements and prolonged sitting or standing with back pain. A research about the different levels of evidence of the relationship of back pain with ergonomic risk factors, found that there is a strong evidence for manual handling, mild evidence for awkward postures and insufficient evidence for static work posture [6]. It is important to note that all these associations were stronger for women than for men. Besides the double burden of job and family demands, women are usually exposed to a worse psychosocial work environment than men [19], which might explain these gender differences.

A limitation of this study is that it excluded informal workers, which have been linked to poorer working and employment conditions and health outcomes [21]. It is possible that the informal working population in Quito has a higher prevalence of back pain than the formal one, as has been found in several Latin American countries [13]. Another important limitation is that this study did not analyze work-family conflict and psychosocial work environment, which have been found to be important determinants of back pain [16, 22].

In conclusion, back pain is frequent among the formal working population in Quito, the capital city of Ecuador, especially among women engaged in low job categories. In addition, awkward postures, manual handling, repetitive movements and prolonged sitting or standing are associated with back pain or discomfort, for both women and men, although these associations are stronger among women. Consequently, monitoring ergonomic exposures should be prioritized. Moreover, future research should incorporate a multidisciplinary approach, exploring on the relationship between ergonomic risk factors, psychosocial exposures and family demands with back pain.

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References

1. EU-OSHA: OSH in figures: Work-related musculoskeletal disorders in the EU-Facts and figures. Luxembourg (2010). https://osha.europa.eu/es/tools-and-publications/publications/reports/TERO09009ENC
2. Benavides, F.G., et al.: Working conditions and health in Central America: a survey of 12, 024 workers in six Countries. Occup. Environ. Med. **71**, 459–465 (2014)
3. Driscoll, T., et al.: The global burden of occupationally related low back pain: estimates from the Global Burden of Disease 2010 study. Ann. Rheum. Dis. **73**, 97–981 (2014)
4. Hoogendoorn, W.E., et al.: Flexion and rotation of the trunk and lifting at work are risk factors for low back pain: results of a prospective cohort study. Spine **2000**(25), 3087–3092 (2000)
5. Punnett, L., Fine, L.J., Keyserling, W.M., Herrin, G.D., Chaffin, D.B.: Back disorders and nonneutral trunk postures of automobile assembly workers. Scand. J. Work Environ. Health **17**, 337–346 (1991)
6. Bernard, BP.: Musculoskeletal disorders and workplace factors. A critical review of epide-miologic evidence for work-related musculoskeletal disorders if the neck, upper extremity, and low back, Cincinatti, OH: National Institute for Occupational Safety and Health. U.S. Department of Health and Human Services (1997)
7. Tissot, F., Messing, K., Stock, S.: Studying the relationship between low back pain and working postures among those who stand and those who sit most of the working day. Ergon. **52**, 1402–1418 (2009)
8. Park, J., Lee, N.: First Korean working conditions survey: a comparison between South Korea and EU Countries. Ind. Health **47**, 50–54 (2009)
9. Instituto Nacional de Seguridad e Higiene en el Trabajo. Encuestas Nacionales de Condi-ciones de Trabajo y Gestión de la Prevención. Análisis en línea de los datos. http://encuestasnacionaels.oect.es

10. European foundation for the improvement of living and working conditions. European Working Conditions Survey (2010). https://www.eurofound.europa.eu/surveys/data-visualisation/european-working-conditions-survey-2010
11. Merino-Salazar, P., et al.: Work and health in Latin America: results from the working conditions surveys of Colombia, Argentina, Chile, Central America and Uruguay. Occup. Environ. Med. (2017). (Epub ahead of print)
12. Peñaherrera Silva, M.G., Gómez García, A.R., Vilaret Serpa, A., Suasnavas Bermúdez, P.R.: Diseño Metodológico de la Encuesta sobre Condiciones de Seguridad y Salud en el Trabajo en Ecuador. Innova. Res. J. **1**, 1–14 (2016)
13. Rojas, M., Gimeno, D., Vargas-Prada, S., Benavides, F.G.: Dolor musculoesquelético en trabajadores de América Central: resultados de la I Encuesta Centroamericana de Condiciones de Trabajo y Salud. Rev. Panam Salud Publica **38**, 120–128 (2015)
14. Hoy, D., et al.: A systematic review of the global prevalence of low back pain. Arthritis Rheumatol. **64**, 2028–2037 (2012)
15. Bartley, E.J., Fillingim, R.B.: Sex differences in pain: a brief review of clinical and experimental findings. Br. J. Anaesth. **111**, 52–58 (2013)
16. Buar, H.: Work-family conflict and neck and back pain in surgical nurses. Int J Occup Saf Ergon. **2016**(22), 1–6 (2016)
17. Plouvier, S., Leclerc, A., Chastang, J.-F., Bonenfant, S., Goldberg, M.: Socioeconomic position and low-back pain–the role of biomechanical strains and psychosocial work factors in the GAZEL cohort. Scand. J. Work Environ. Health **35**, 429–436 (2009)
18. Kistensen, P.: Inequalities in health social causation and the role of occupation. Scand. J. Work Environ. Health **34**, 235–238 (2008)
19. Artazcoz, L., Borrell, C., Cortès, I., Escribà-Agüir, V., Cascant, L.: Occupational epidemiology and work related inequalities in health: a gender perspective for two complementary approaches to work and health research. J. Epidemiol. Community Health. **61**(Suppl 2), ii39–ii45 (2007)
20. Campos-Serna, J., Ronda-Pérez, E., Artazcoz, L., Benavides, F.G.: Desigualdades de género en salud laboral en España. Gac. Sanit. **26**, 343–351 (2012)
21. Muntaner, C., Solar, O., Vanroelen, C., et al.: Unemployment, informal work, precarious employment, child labor, slavery, and health inequalities: pathways and mechanisms. Int J Health Srv. **40**, 281–295 (2010)
22. Hoy, D., Brooks, P., Blyth, F., Buchbinder, R.: The Epidemiology of low back pain. Best Pract. Res. Clin. Rheumatol. **24**, 769–781 (2010)

Comparison of Two Post Office Workstation Layouts by Means of an Optoelectronic Motion Analysis System

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Abstract. The aim of the study was to analyze the post office user/customer interface, comparing two workstation layouts. The post office clerk was facing the client in one layout and seated at 45° with respect to the counter in the other. We analyzed the most frequent tasks presenting awkward postures: (1) payment of a postal order; (2) accepting a registered letter. These two tasks were further divided in their subtasks. We used an optoelectronic motion analysis system, and measured the Range of Motion (RoM) of trunk, arms and head. Using equipments placed on the employee left side the 45° workstation layout required less trunk and head torsion. A larger worktop improved the workstation, leaving more room for the equipments and allowing the worker to sit in front of screen and keyboard. However, this solution involved increased RoMs in the activities performed on both sides. The opto-electronic motion analysis system gave quantitative data still at the prototype stage. On the contrary, the most common standardized protocols, based on subjective observations, can give only qualitative evaluations. Furthermore, with the opto-electronic system, differently from simulation software that uses virtual settings, we are able to check the real interaction between the worker and the layout. From the quantitative data we can also extract useful information to help occupational doctors in managing healthcare protocols and to draw up a fuller, real assessment of biomechanical risks. Designers and planners could also use the data to study work layouts focusing at the same time to both on worker and on the process.

Keywords: Office ergonomics · Workplace redesign · User/customer interface · Range of motion

1 Introduction

Notwithstanding the technological evolution and digitalisation of many operations, which, nowadays, can be carried out through our smartphones, some public services (i.e. banks, post offices, private postal services, public institution help desks, shops, etc.)

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cannot be completely digitalised. In most cases, customer/operator interfaces have specific short-term functional requirements for the customer, not taking into account the long-term postural needs of the operators. Excessive digitalisation has also led to a paradox: the amount of equipment has increased at the workstation, thus reducing the already limited availability of space at the traditional workstations. Various guidelines and checklists [1–4] underline the importance of correct positioning for the most frequently used equipment, allowing easy access for the operator. In the services sector (banks, shops, supermarkets, etc.). When designing a workstation, both the movements related to the use of the various equipment (POS, scales, scanners, cash, monitors etc.) as well as the movements related to customer interaction shall be considered. Every modification to a workstation and equipment affects not only the performance, but also the biomechanical risk. Sengupta [5] noted that energy expenditure was closely related to the reach zone breadth (reach envelope).

Several studies have investigated the reach envelope under static conditions but without taking trunk movements into account [6–9]; more recent studies have also considered dynamic conditions [10]. This study aims at comparing two customer/operator interfaces: (1) the operator is sitting in front of the customer; (2) the operator is sitting at a 45° angle to the customer, in line with the monitor and keyboard. For this comparative study, starting with a workstation prototype to analyse, some modifications were suggested, whose efficacy was assessed through a motion analysis system.

2 Materials and Methods

This study focuses on the two most frequent tasks, which appear to be also the most critical ones from a biomechanical point of view: (1) payment of a bill (2) weighing and taking payment for sending a registered letter. For greater ease of analysis, the two tasks were broken down into the following sub-tasks. Task 1 was broken down as follows: (1a) withdrawal of the bill by the customer and put on the scanner; (1b) typing data and picking up the bill from the scanner; (1c) taking the money from the customer and typing in the amount; (1d) getting the change (banknotes and coins) and the bill and returning it to the customer. Task 2 was broken down as follows: (2a) taking the customer's envelope and placing it on the scales; (2b) picking up and scanning the tracking form and placing it on the printer; (2c) removing the envelope from the scales and inserting/removing it from the franking machine and placing it in the outgoing post box (2d) taking the receipt from the printer, sticking the receipt to the envelope and placing the letter in the outgoing post box.

For each sub-task, the Range of Motions (RoM) for the trunk and the shoulders in three spatial planes (frontal, sagittal, transverse), the elbows extension and the head torsion were calculated. The chair rotation angle, in respect to the table, was also measured.

Analysis of two different working desk types was made:

(1) Front-facing positioning of the operator in respect to the customer, leaving spaces and equipment placement unaltered, as during daily operations, with the original counter.

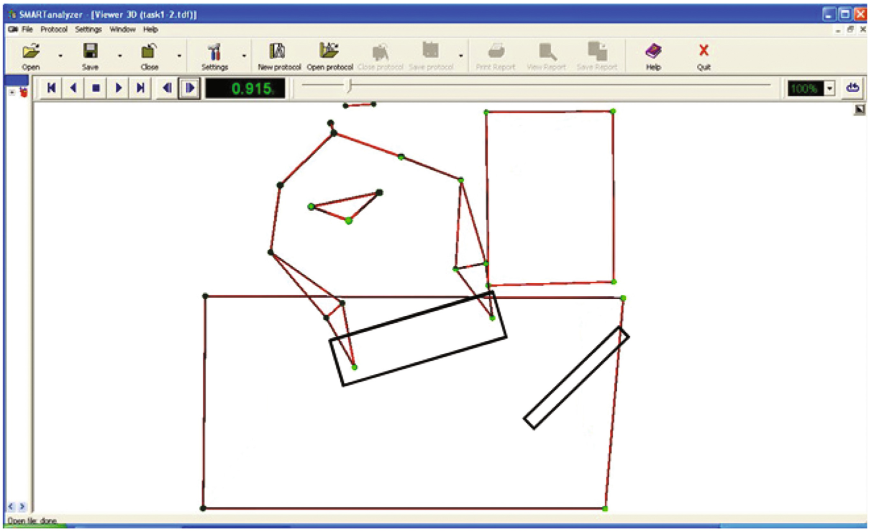

Fig. 1. The image shows a kinematic reconstruction of the operator's starting position at the unaltered workstation. The rectangles with a darker border represent the position of the monitor and keyboard (the latter are not to scale).

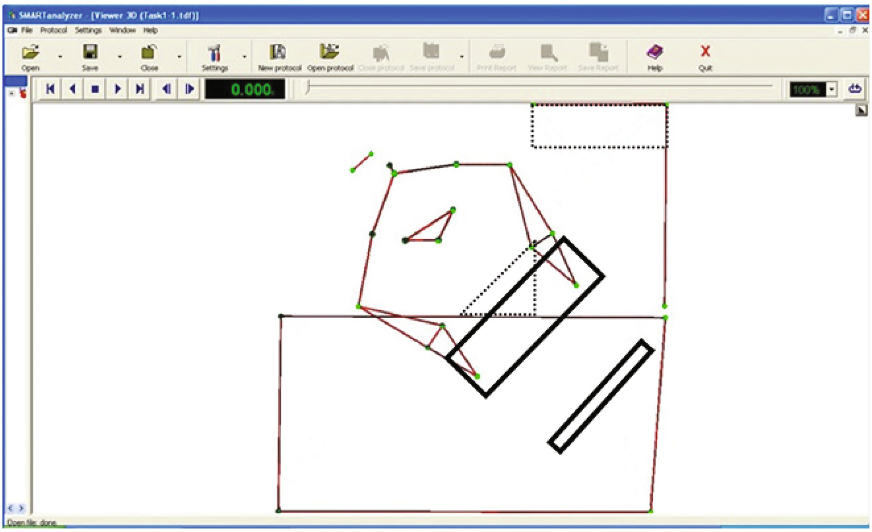

Fig. 2. The image shows a reconstruction of the operator's starting position at the modified workstation. For this, the operator is aligned with the keyboard and monitor (the rectangles with the darker borders are not to scale in this reconstruction). The areas with dashed borders represent the modifications made to the workstation addition of a triangular part to align the monitor and keyboard and to allow forearm support together with lengthening the board to allow equipment placement (not to scale in this reconstruction).

(2) 45° positioning of the operator in respect to the customer, made possible by the addition of a triangular structure connecting the working desk and a board of extended size on the left side of the operator.

The images below illustrate, respectively, the operator's starting position for front-facing positioning (Fig. 1) and at 45° (Fig. 2) at the modified workstation.

2.1 Participants

Four workers with more than 5 years of experience in the activity sector participated in the study. Their average age was 49 (±5.2), an average height of 177 cm (±3.9) and average weight of 81 kg (±3.1). None of the participants had ever suffered from musculoskeletal disorders.

2.2 Equipment

An optoelectronic system for the kinematic motion analysis was used (SMART-DX6000, BTS, Milan, Italy) [11], consisting of eight infrared cameras (sampling frequency 340 Hz), for recognising passive reflective markers coated with aluminium dust and positioned in specific anatomical landmarks in accordance with Rab protocol [12]. Other markers were positioned on the two temporal regions, in the centre of the forehead and on the edges of the chair, in order to investigate trunk and head torsion.

2.3 Detailed Description of the Analysed Sub-tasks

Bill Payment Task. *Task 1a.* Starting with their hands on the keyboard, they take the bill, check the bill, place it on the scanner and return hands to the keyboard;

Task 1b. Starting with their hands on the keyboard, they type 08081959, two tabs and send to the numeric keypad, wait two seconds, take the bill from the scanner and put it in front of the keyboard, return hands to the keyboard;

Task 1c. Starting with their hands on the keyboard they take the customer's money, check the money, put the money on the keyboard, type 50, tab and send on the numeric keypad, return hands to keyboard;

Task 1d. Starting with their hands on the keyboard and the bill in front of the keyboard, take a banknote from the draw to the furthest right, move the banknote to the left, take the change (20 cent more) from the till with the right hand and pass it to the left, take the bill with the right hand, pass the change and the bill to the right, give them back to the customer, return hands to the keyboard.

Registered Letter Acceptance Task. *Task 2a.* Starting with their hands on the keyboard, they take the envelope from the customer with the right hand, pass the envelope to the left hand and place it on the scales, return hands to the keyboard;

Task 2b. Starting with their hands and the registered letter in front of the keyboard, take the form with their right hand, place the form on the scanner with the right hand and put it in the right hand side of the printer;

Task 2c. Starting with their hands on the keyboard, take the envelope from on top of the scales with their left hand and put it in the left hand side of the franking machine, take the envelope from the right hand side of the franking machine with the right hand, pass the envelope to the left hand and place it in the box, return hands to the keyboard;

Task 2d. Starting with their hands on the keyboard, take the return receipt from the printer, detach the return receipt tabs with the right hand, stick the return receipt to the envelope with both hands, take the envelope with the left hand and put it in the box, return hands to the keyboard.

2.4 Kinematic Analysis

Following a frame by frame reconstruction procedure, to assign each track the respective marker (Smart Tracker, BTS, Milan, Italy), the acquired data was processed using Analyzer software (Smart Analyzer, BTS, Milan, Italy).

The movement always started from the same position (sitting in front of the customer in position 1 in front of the monitor in position 2). The RoMs were calculated for: trunk torsion, flexion and lateral bending; abduction, horizontal abdo-adduction and flexion-extension of the shoulders; elbow extension and head torsion. The chair rotation angle, in respect to the table, was also measured. The kinematic signals were finally processed using a low pass filter with 5 Hz frequency. Five tests were carried out on each sub-task.

2.5 Statistical Analysis

The statistical analysis was performed using SPSS 17.0 software (SPSS Inc., Chicago, IL, USA). For each RoM, the average and standard deviation were calculated, to which the Student t-test was applied for paired data. P-values lower than 0.05 ($p < 0.05$) were considered statistically significant.

3 Results

Below are the results of the kinematic analysis of each investigated subtask, were a statistically significant difference was reported ($p < 0.05$).

Task 1a: complete torsion (trunk + head) remained essentially unaltered (about 37° overall), but differently distributed. The modified workstation allowed for minor torsion of the trunk (10.5° Vs 22.6°), but higher torsion of the head (27.5° Vs 14.9°). The modified workstation allowed for a reduced RoM value for the right shoulder in all three of the spatial planes: abduction (41.8° Vs 54.1°), horizontal abdo-adduction (28.4° Vs 33.2°) and flexion-extension (55.1° Vs 61.8°). Moreover, at the modified workstation the trunk torsion and lateral bending values were lower (17.4° Vs 24.6°), (26.7° Vs 37.4°).

Task 1b: The modified workstation allowed for reduced rotation of both the trunk (value of 11.1° Vs 17.2°) and head (7.9° Vs 12.9°). Statistically significant reductions were also noted in flexion (4.8° Vs 13.7°) and lateral bending (11.2° Vs 31.6°), in the right shoulder (39.9° Vs 59.2°) and the left shoulder (10.6° Vs 14.5°) flexion, abduction of the right shoulder (33.5° Vs 49.9°), horizontal abdo-adduction of the right shoulder (26.7° Vs 38.6°) and left shoulder (9.1° Vs 19°) and left elbow extension (20.1° Vs 25.6°). Finally, the modified position allowed for reduced chair rotation (value of 2.2° Vs 6.6°).

Task 1c: This task was almost exclusively carried out with the operator's right arm. Overall, the modified workstation showed high rotation values (trunk and head) in comparison to the original position (33.2° Vs 27.5°). Similarly, to what reported for task 1a, in this task the operators adopted a different motor strategy when rotating. In fact, the modified workstation showed lower values of trunk torsion (6.9° Vs 11°), but higher head torsion values (26.3° Vs 16.5°). The modified workstation also showed lower values for trunk flexion (4.8° Vs 13.7°) and trunk lateral bending (11.2° Vs 31.6°), right shoulder flexion (38.1° Vs 50.4°), right elbow extension (63.4° Vs 93°), right shoulder abduction (33.5° Vs 49.9°) and finally, right shoulder horizontal abdo-adduction (26.7° Vs 38.6). For this task, chair rotation was lower in the unaltered workstation (1.8° Vs 5.3°).

Task 1d: This task actively involved both upper limbs. Here, the modified workstation showed higher chair rotation values (18.6° Vs 15.4°) but lower overall torsion values for body parts, both for the trunk (21.6° Vs 33.8°), and the head (26.7° Vs 34.9°). The changed position showed reduced RoM and reduced abduction values for both shoulders (right 47.5° Vs 62.3° and left 7.9° Vs 12.9°), reduced horizontal abdo-adduction for the right shoulder (43.2° Vs 61.7°) and left elbow extension (39.2° Vs 52.3°). A significant reduction was also reported, although not statistically significant, of the extension of both elbows. Flexion and trunk lateral bending remained substantially unchanged.

Task 2a: the task in the modified workstation showed a statistically significant reduction in head torsion (27.8° Vs 33.5°), extension of both elbows (right 56.6° Vs 83.3°; left 47.1° Vs 62.7°), right shoulder flexion (31.7° Vs 50.8°) and horizontal abdo-adduction of the right shoulder (23.7° Vs 46.9°). The unaltered workstation showed lower statistically significant values of left shoulder abduction (30.5° Vs 41.3°). The modifications made to the workstation did not lead to statistically significant differences in the RoMs related to trunk, in any of the three spatial planes for this task.

Task 2b: Contrary to those previously described, this task was carried out entirely on the right side of the operator. The modifications introduced produced an overall increase in rotation (48.9° Vs 42°) trunk torsion was reduced in the modified workstation (9.9° Vs 29.3°), but head rotation was significantly increased (39.1° Vs 12.7°). In this task, chair rotation was reduced in the modified workstation, although slightly, (4.3° Vs 7.7°). The modified workstation also showed higher RoM values for the operator's right side, in particularly for elbow extension (84.8° Vs 58.6°), shoulder flexion (69.1° Vs 48.2°) and shoulder abduction (43.9° Vs 20.2°). However, the modified workstation showed reduced RoM values for horizontal abdo-adduction of the right shoulder (46° Vs 61.8°).

Task 2c: This task was carried out exclusively on the operator's left side. The modified workstation showed lower values for chair rotation (32.2° Vs 50.2°), trunk rotation (16.2° Vs 21.5°) and trunk lateral bending (35.2° Vs 54.5°) and right elbow extension (51.7° Vs 60.9°). However, the modified workstation showed higher values of flexion for shoulders (right 39.6° Vs 28°; left 60.8° Vs 38.8°), left shoulder abduction (44.2° Vs 34.9°) and left elbow extension (70.6° Vs 63°).

Task 2d: In this task – unlike all the abovementioned tasks – the operator moved on both sides of the workstation. The modified workstation showed high RoM values with regards to trunk torsion (23.1° Vs 16.4°) and left shoulder flexion (35.4° Vs 26.8°), but reduced RoM values for chair rotation (18.1° Vs 39.3°), trunk lateral bending (30.5° Vs 50°), left shoulder abduction (12.5° Vs 19°) and horizontal adduction of the right shoulder (26° Vs 35.7°). The modified workstation showed higher values, although not statistically significant, in terms of extension for both elbows (right 63.7° Vs 57.2°; left 72.2° Vs 69°).

Tables 1, 2, 3, 4, 5 and 6 summarise the abovementioned results, along with relevant statistical analysis (statistically significant differences $p < 0.05$ are reported in bold) for chair rotation and for each movement under investigation.

Table 1. The table shows the average chair rotation (±SD) achieved relating to the desk and the relevant statistical analysis for each of the eight sub-tasks analysed.

Task	Chair rotation		
	Front-facing	45°	*p*
Task1a	4.2 ± 0.9	4.3 ± 0.9	0.8066
Task1b	6.6 ± 1.9	2.2 ± 0.4	**0.000001**
Task1c	1.8 ± 0.4	5.3 ± 3.7	**0.0081**
Task1d	15.4 ± 4.2	18.6 ± 1.6	**0.0371**
Task2a	3.8 ± 2.8	3.1 ± 0.8	0.457
Task2b	7.7 ± 2	4.3 ± 2.1	**0.0016**
Task2c	50.2 ± 8.7	32.2 ± 7.8	**0.001**
Task2d	39.3 ± 8	18.1 ± 6.2	**0.000003**

Table 2. The table shows the average RoMs (±SD) achieved for head torsion and the relevant statistical analysis for each of the eight sub-tasks analysed.

Task	Head torsion		
	Front facing	45°	*p*
Task 1a	14.9 ± 1.2	27.5 ± 2.7	**0.0000**
Task 1b	12.9 ± 1.8	7.9 ± 1.4	**0.0000**
Task 1c	16.5 ± 2.2	26.3 ± 2.6	**0.0000**
Task 1d	34.9 ± 3.2	26.7 ± 8.7	**0.0119**
Task 2a	33.5 ± 2.9	27.8 ± 2.2	**0.0001**
Task 2b	12.7 ± 1	39 ± 1.1	**0.0000**
Task 2c	41.3 ± 3.7	41.7 ± 3.1	0.7963
Task 2d	41 ± 13.1	42.8 ± 2.1	0.6730

Table 3. The table shows the average RoMs (±SD) achieved for the three spatial planes of the trunk and the relevant statistical analysis for each of the eight sub-tasks analysed.

Task	Trunk flexion			Trunk lateral bending			Trunk torsion		
	Front facing	45°	*p*	Front facing	45°	*p*	Front facing	45°	*p*
Task 1a	24.6 ± 3.5	17.4 ± 3.3	**0.0002**	37.4 ± 2.1	26.7 ± 4.4	**0.0000**	22.6 ± 1.5	10.5 ± 1.3	**0.0000**
Task 1b	13.7 ± 4.7	4.8 ± 0.9	**0.0000**	31.6 ± 2.8	11.2 ± 2.7	**0.0000**	17.2 ± 2.7	11.1 ± 1.1	**0.0000**
Task 1c	22.3 ± 3.7	15.9 ± 1.8	**0.0001**	31.6 ± 6.1	22.2 ± 2.7	**0.0003**	11 ± 1.9	6.9 ± 1.7	**0.0001**
Task 1d	29 ± 3.3	27.7 ± 10.4	0.7107	34.5 ± 2.6	28.3 ± 10	0.0739	33.8 ± 2.8	21.6 ± 7.3	**0.0001**
Task 2a	19.2 ± 2.7	19.8 ± 3.2	0.6558	31.2 ± 2.5	31.4 ± 3	0.8731	11.3 ± 1.8	10.1 ± 1.8	0.1534
Task 2b	8.5 ± 1.8	7.2 ± 3.3	0.2885	17.4 ± 2.7	17.5 ± 4.2	0.9502	29.3 ± 1.5	9.9 ± 1.1	**0.0000**
Task 2c	35.4 ± 4.1	32.6 ± 5.8	0.2285	54.5 ± 5.5	35.2 ± 3.4	**0.0000**	21.5 ± 1.5	16.2 ± 3.4	**0.0001**
Task 2d	25.8 ± 8.6	19.9 ± 4.6	0.0718	50 ± 14.7	30.5 ± 5.5	**0.0010**	16.4 ± 5.3	23.1 ± 2.4	**0.0019**

Table 4. The table shows the average RoMs (±SD) achieved for the three spatial planes of right (R) shoulder and the relevant statistical analysis for each of the eight sub-tasks analysed.

Task	R shoulder abduction			R shoulder Horizontal abd-adduction			R shoulder flexion		
	Front facing	45°	*p*	Front facing	45°	*p*	Front facing	45°	*p*
Task 1a	54.1 ± 2.2	41.8 ± 2.8	**0.0000**	33.2 ± 4.5	28.4 ± 2.8	**0.0103**	61.8 ± 3.8	55.1 ± 4.7	**0.0025**
Task 1b	49.9 ± 4.4	33.5 ± 2.1	**0.0000**	38.6 ± 5	26.7 ± 2.6	**0.0000**	59.2 ± 4	39.9 ± 2.9	**0.0000**
Task 1c	48 ± 2.9	32.7 ± 3.1	**0.0000**	23.1 ± 5.4	17.5 ± 2.5	**0.0081**	50.4 ± 3.8	38.1 ± 5.2	**0.0000**
Task 1d	62.3 ± 3.3	47.5 ± 16.1	**0.0107**	61.7 ± 4.8	43.2 ± 14.7	**0.0014**	47.8 ± 2.6	46.5 ± 15.7	0.7991
Task 2a	37.5 ± 5.8	34 ± 4.3	0.1427	46.9 ± 6.3	23.7 ± 4.5	**0.0000**	50.8 ± 4.1	31.7 ± 2.8	**0.0000**
Task 2b	20.2 ± 2.8	43.9 ± 2.6	**0.0000**	61.8 ± 3.3	46 ± 3.3	**0.0000**	48.2 ± 2.5	69.1 ± 2	**0.0000**
Task 2c	14.8 ± 2.3	16.2 ± 4.7	0.4086	44 ± 4.9	46.1 ± 8.7	0.5144	28 ± 3	39.6 ± 5.5	**0.0000**
Task 2d	20.5 ± 6.5	21.3 ± 2.8	0.7249	35.7 ± 9.6	26 ± 4.4	**0.0094**	24.6 ± 6.8	26.7 ± 3	0.3834

Table 5. The table shows the average RoMs (±SD) achieved for the three spatial planes of left (L) shoulder and the relevant statistical analysis for each of the eight sub-tasks analysed.

Task	L shoulder abduction			L shoulder Horizontal abd-adduction			L shoulder flexion		
	Front-facing	45°	*p*	Front-facing	45°	*p*	Front-facing	45°	*p*
Task 1a	7.6 ± 1.6	12.4 ± 2.7	**0.0001**	25.8 ± 6.2	21.8 ± 6	0.1599	14.4 ± 3.5	16.7 ± 3.9	0.1821
Task 1b	7.3 ± 4	7.6 ± 1	0.8798	19 ± 3.5	9.1 ± 1.2	**0.0000**	14.5 ± 2.8	10.6 ± 1.3	**0.0008**
Task 1c	9.5 ± 2.1	12.5 ± 3.3	**0.026**	19.1 ± 3.4	20.3 ± 3.2	0.4270	17.4 ± 3	25.8 ± 3.5	**0.0000**
Task 1d	12.9 ± 3.2	7.9 ± 2.8	**0.0016**	50.9 ± 2.8	42.2 ± 14.3	0.0752	33.9 ± 3	28.4 ± 9.9	0.1100
Task 2a	30.5 ± 11.2	41.3 ± 4.5	**0.0111**	42.5 ± 17.6	36.4 ± 4	0.2993	25.1 ± 9.9	27.6 ± 2.4	0.4478
Task 2b	10.6 ± 1.9	5.5 ± 1.2	**0.0000**	20.8 ± 1.2	17.4 ± 5.3	0.0634	11.4 ± 2.1	11.3 ± 5.4	0.9571
Task 2c	34.9 ± 3.8	44.2 ± 2.9	**0.0000**	49.3 ± 3.1	49.5 ± 4.2	0.9049	38.8 ± 6	60.8 ± 6.9	**0.0000**
Task 2d	19 ± 7.1	12.5 ± 1.7	**0.0115**	39.5 ± 11	46.9 ± 2.8	0.0540	26.8 ± 8.1	35.4 ± 4.7	**0.0095**

Table 6. The table shows the average RoMs (± SD) achieved for extension of both of the elbows and the relevant statistical analysis for each of the eight sub-tasks analysed.

Task	R elbow extension			L elbow extension		
	Front-facing	45°	*p*	Front facing	45°	*p*
Task 1a	94.9 ± 6.8	94.8 ± 6.9	0,9743	36.3 ± 5.7	32 ± 3.4	0.0554
Task 1b	69.1 ± 5	68.9 ± 4.9	0.9290	25.6 ± 6.2	20.1 ± 3	**0.0212**
Task 1c	93 ± 2.3	63.4 ± 3.5	**<0.0000**	35.8 ± 4.1	27.8 ± 3.5	**0.0002**
Task 1d	109.7 ± 7.7	103 ± 34.6	0.5575	52.3 ± 7.9	39.2 ± 13.5	**0.0163**
Task 2a	83.3 ± 6.4	56.6 ± 11.4	**<0.0000**	62.7 ± 10.8	47.1 ± 5.5	**0.0007**
Task 2b	58.6 ± 3.8	84.8 ± 3.2	**<0.0000**	22.4 ± 4.7	17.5 ± 5.8	0.0525
Task 2c	60.9 ± 7.6	51.7 ± 5.2	**0.0054**	63 ± 2.6	70.6 ± 6.9	**0.0044**
Task 2d	57.2 ± 17	63.7 ± 5.1	0.2620	69 ± 22.8	72.2 ± 9	0.6846

4 Discussion

The changes made to the workstation, especially the introduction of a connecting board allowing for the alignment of the operator with the monitor and keyboard, appeared to bring improvement in the sub-tasks 1a, 1b, 1c 1d and 2a, which is in those where the operator carried out operations mainly in the central and left side of the workstation and involved interaction with customers. According to the data provided to us, these tasks are among those most frequently performed by operators. In particular, the RoMs for lateral bending and flexion were reduced, while as regards rotation, it was noticed that the workers adopted a different motor strategy, which provided for a broader movement of the head rather than the trunk. This change appeared to lead to a worsening in the case of sub-tasks 2b and 2c. In fact, in sub-task 2b, the re-design intervention moved the operator further away from the right side of the workstation, where the printer was located, thus leading to an increase of ROMs for elbow extension, as well as for right shoulder flexion and abduction. Nevertheless, according to the data provided to us, this subtask resulted in being the least frequent among those actually performed. Meanwhile, in subtask 2 the change lead to a worsening for upper limb movements, in that the operator, in order to place the envelope on the scales/franking machine, had to raise their shoulder and extend their elbow further because of the machine overall size. However, the alteration involved improvements to the transverse plane resulting in reduced chair rotation and reduced trunk torsion. The modifications to the workstation in sub-task 2d, the only one involving actions performed on both sides of the operator, resulted in advantages and disadvantages. In fact, the RoM values were reduced in regards to trunk lateral bending, left shoulder abduction and right shoulder horizontal abdo-adduction, but were greater for trunk torsion and right shoulder flexion. However, the increase in trunk torsion by 6.7° was largely offset by the reduction in chair rotation by 21.2°.

The activities carried out in the laboratory showed the need to remove the solid metal footrest fixed and permanently joint to the counter because it interfered with the base of the operator's chair.

As a conclusion, the change in the working desk, made with the introduction of a board joined to the original straight working desk, allowed the operator to align with the monitor and keyboard as well as providing adequate support for the forearms while typing, that, according to published data [13], also allowed for muscle engagement reduction while typing on the keyboard. The change appeared to bring improvement for most of the sub-tasks investigated, both in terms of trunk torsion and lateral bending, as well as in terms of interaction with the equipment located on the left side of the workstation. The flexion-extensions were also reduced in both upper limbs and trunk during customer interaction. Conversely, the change appeared to lead to worsening, when the operator worked on the right side of their workstation.

To reduce overall head and trunk rotation, it would be appropriate to provide the operator with a seating that allows the operator to rotate the seating plan rather than their trunk and/or head.

Furthermore, it would be useful to provide a chair that allows for an easy transition between sitting and standing positions. This is in view of the fact that, from the information supplied to us, when working at the counter the operator often stands up (for example, taking forms from the cabinets, photocopying, picking up/consulting documents, processing manager requests, etc.) and moves therefore from sitting position.

Finally, it would be appropriate to provide the workstation with devices that are less cumbersome as possible, to allow them to be better distributed on the working desk. This arrangement would lead to a better interaction of the worker with the equipment and would allow for a greater availability of space, thus providing a more correct positioning of the operator at the workstation.

References

1. NIOSH: Public Health Service. NIOSH Publications on Video Display Terminals (Revised). NIOSH, Cincinnati, OH (1991)
2. OSHA, Department of Labor, Working Safely with Video Display Terminals (1997)
3. SUVA: Il lavoro al videoterminale informazioni dettagliate per specialisti e non (2003)
4. INAIL: Il Lavoro al videoterminale. A cura di Barbara Manfredi. Stampato dalla Tipolitografia INAIL di Milano (2010). ISBN 978-88-7484-169-1
5. Sengupta, A.K., Das, B.: Determination of worker physiological cost in workspace reach envelopes. Ergonomics **47**, 330–342 (2004)
6. Roth J.T., Ayoub M.M., Halcomb C.G.: Seating console and workplace design: seated operator reach profiles. In: Proceedings of the Human Factors Society, 21st Annual Meeting, pp. 83–87 (1977)
7. Haslegrave, C.M.: Characterizing the anthropometric extremes of the population. Ergonomics **29**, 281–301 (1986)
8. Das, B., Behara, D.N.: Determination of the normal horizontal working area: a new model and method. Ergonomics **38**, 734–748 (1995)
9. Sengupta, A.K., Das, B.: Maximum reach envelope for the seated and standing male and female for industrial workstation design. Ergonomics **43**, 1390–1404 (2000)
10. Holman, G.T., Davis, J., Maghsoodloo, S.: The effects of dynamic movement on seated reach arcs. Ergonomics **51**, 691–701 (2008)

11. Ferrigno, G., Pedotti, A.: ELITE: a digital dedicated hardware system for movement analysis via real-time TV signal processing. IEEE T. Bio-Med. Eng. **32**, 943–950 (1985)
12. Rab, G., Petuskey, K., Bagley, A.: A method for determination of upper extremity kinematics. Gait Posture **15**, 113–119 (2002)
13. Cook, C., Burgess-Limerick, R., Papalia, S.: The effect of upper extremity support on upper extremity posture and muscle activity during keyboard use. Appl. Ergon. **35**(3), 285–292 (2004)

A Review Study on Biodynamic Response of Seated Occupants Exposed to Whole Body Vibration

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Abstract. This review study investigated seated human biodynamic responses while exposed under vehicle vibrations. Primary focus of study is to explore such biodynamic investigations under tractor driving occupations in India. Out of 127 research articles, 19 found to be suitable as per the aim of study in between a year span of 2010-till date. Majority of studies are performed on controlled simulated laboratory set-ups, rather than considering same investigations under real field conditions. Besides, vibration power absorbed function has been found to be least explored as compared to other biodynamic functions. However, none of selected studies explored biodynamic response investigations of Indian tractor drivers while performing on road as well as off-road activities, which is an existing gap in literature. Therefore, detailed biodynamic studies are required under Indian terrain conditions to limit whole body vibration related health disorders by incorporating suitable preventive measures.

Keywords: Whole body vibration (WBV) · Tractor · Ride comfort · Biodynamics · Health hazards

1 Introduction

Vibrations arise in every moving vehicle so tractors are no exception. Each human body tends to vibrate at some degree while driving or travelling in any on-road as well as off-road vehicle [1]. Human body is quiet sensitive to low frequency vibration which may disturbs adversely in terms of health related disorders. Moreover, 2–6 Hz frequency range is considered as very influencing on human body due to occurrence of resonance [1]. Tractors are considered as the backbone of agriculture which are extensively used for both on-road and off-road transportation and field operations. Usually in all agricultural tasks, tractor drivers works under low frequency vibrations that can impair the performance of driver and ultimately cause under-utilization of available power of machinery [2]. However, vibration levels in tractor are higher in

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comparison to other on-road vehicles as per internationally accepted levels [3, 4]. On the other hand, biodynamic investigations have been very popular in recent literature. In simple form, biodynamics investigation provides motion-motion as well as force-motion relationships while exposed to vibrations [5]. Out of these functions, transmissibility comes under motion-motion category and rest two under force-motion study of human body under vibrating environment [6].

Primarily, present review elaborated biodynamic investigations of seated human body exposed to whole body vibrations. Especially, study has been performed to explore the role of biodynamics in tractor drivers of Indian region. Therefore, it is a step-forward towards such investigations that usually less explored in developing countries like India.

2 Method/Approach

A systematic methodology has been mentioned in flow chart Fig. 1. The study collected a number of research articles from various reputed Thomson Reuters Indexed journal from a year 2010 to till date. The various incorporated journals are: Journal of Sound and Vibration, Journal of Low Frequency Noise, Vibration-Active Control, Vehicle System Dynamic, International Journal of Vehicle Noise and Vibration, Ergonomics, Medical Engineering and Physics, Applied Ergonomics, International Journal of Industrial Engineering, International Journal of Automotive Technology.

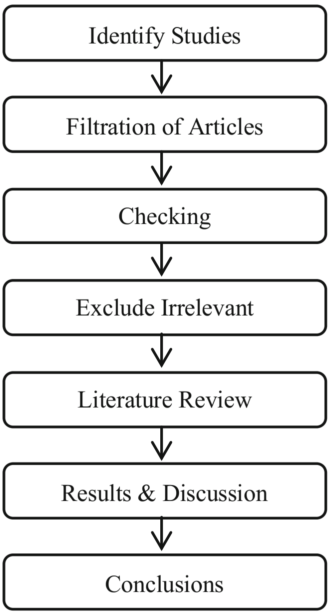

Fig. 1. Flow chart of methodology

Furthermore, search extended to books, conferences, thesis and other useful study materials. By considering all, a final database summarized chronologically in order to present needful information from selected research articles. After summarization, results have been discussed and concluded accordingly. Moreover, study also exhibits some research potentials for future researches.

3 Results and Discussion

During identification process, around 127 research articles found to be based on biodynamic investigation under various conditions. While pre-checking, studies found to include standing as well as recumbent postures of human body while evaluating biodynamic functions. However, study focused on seated body, about 81 studies out of 127 excluded from database. Afterwards, step-1 of screening process filters articles by observing titles, abstract and keywords but reading of full text in step-2 after step-1 filtration. This screening eliminated 27 articles, which were irrelevant to focus of study. Further, some articles found duplicate, hence excluded and final database incorporates 19 research articles (Fig. 2).

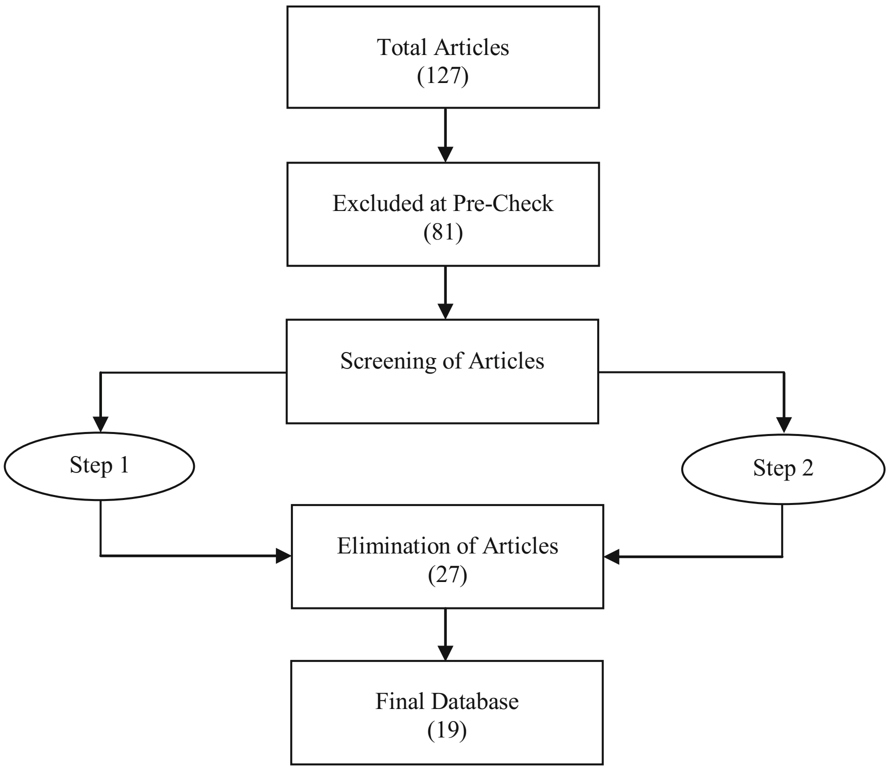

Fig. 2. Selection route of studies for review

These studies have been summarized in a tabular form that addresses a number of key points such as type of study, input of vibration stimuli, direction of measurement and type of biodynamic function as an output of study. This information is quite essential while performing experimentation of such biodynamic investigations. Table 1 shows summarization of selected studies as follows:

Table 1. Summarized data of selected research articles

Study	Study type		Input vibration		Response axis			Biodynamic function		
	Lab	Field	Random	Sinusoidal	X	Y	Z	APMS	T	VPA
[7]	✓	–	✓	–	–	–	✓	✓	–	–
[8]	✓	–	✓	–	–	–	✓	✓	–	–
[9]	✓	–	✓	–	–	–	✓	✓	✓	–
[10]	✓	–	✓	–	–	–	✓	–	✓	–
[11]	✓	–	✓	–	✓	–	✓	–	✓	–
[12]	✓	–	✓	–	✓	✓	✓	–	–	✓
[13]	✓	–	✓	–	✓	–	–	✓	✓	–
[14]	✓	–	–	✓	–	–	✓	–	✓	–
[15]	✓	–	✓	–	✓	✓	✓	–	✓	–
[16]	✓	–	✓	–	–	✓	–	–	✓	–
[17]	–	✓	▲	▲	✓	✓	✓	–	✓	–
[18]	✓	–	✓	–	–	–	✓	✓	✓	–
[19]	✓	–	✓	–	–	–	✓	✓	–	✓
[20]	✓	–	✓	–	✓	–	✓	–	✓	–
[21]	✓	–	✓	–	✓	✓	✓	✓	✓	–
[22]	–	✓	▲	▲	–	–	✓	–	✓	–
[23]	–	✓	✓	–	✓	✓	✓	–	✓	–
[24]	✓	–	–	✓	✓	✓	✓	✓	✓	–
[25]	✓	–	–	✓	▲	▲	▲	✓	–	–

✓ (Considered), - (Not Considered), ▲ (Not Reported), x (Fore-and-aft Axis), y (Lateral Axis), z (Vertical Axis).

Above table resulted that 84% of biodynamic investigations have been performed under controlled simulated laboratory set-ups except 16% of field studies. However, field measurements only targeted transmissibility response evaluation rather than APMS and VPA functions. Majority of investigations have been performed under vertical axis of excitation followed by x and y-axis respectively. Only three studies considered sinusoidal vibration, however, rest all used random vibrations to conduct experimentation. Moreover, 79% of studies evaluated transmissibility function followed by APMS and VPA to study biodynamic responses. A few studies explored VPA as a better measurement of such responses among other transmissibility and apparent mass functions. At present, VPA has been seen as least explored function in selected studies. The study incorporates literature from a number of reputed journals as mentioned in methodology section. However, International journal of Industrial Ergonomics contributes maximum (21.05%) towards biodynamics research publications from 2010 to till date. Consequently, Journal of Sound and Vibration, Journal of Low Frequency Noise, Vibration-Active Control and International Journal of Vehicle Noise and Vibration exhibits 15.79% contribution followed by other journals as described in Table 2.

Table 2. Percentage contribution of selected journals from 2010-till date

List of Journals	Years								Total Contribution from 2010- till date
	2010	2011	2012	2013	2014	2015	2016	2017	
Journal (A)	1	2	-	-	-	-	-	-	15.79%
Journal (B)	-	-	1	1	-	1	-	-	15.79%
Journal (C)	-	1	-	-	-	-	-	-	5.27%
Journal (D)	-	-	-	-	1	1	1	-	15.79%
Journal (E)	-	-	-	-	1	1	-	-	10.50%
Journal (F)	1	-	-	-	-	-	-	-	5.27%
Journal (G)	-	-	-	-	1	-	-	-	5.27%
Journal (H)	-	-	1	1	-	2	-	-	21.05%
Journal (I)	-	-	-	-	-	-	-	1	5.27%

Journal (A): Journal of Sound and Vibration,**Journal (B):**Journal of Low Frequency Noise,Vibration-Active Control, **Journal (C):**Vehicle System Dynamic, **Journal (D):**International Journal of Vehicle Noise and Vibration, **Journal (E):**Ergonomics, **Journal (F):**Medical Engineering and Physics, **Journal (G):**Applied Ergonomics, **Journal (H):**International Journal of Industrial Engineering, **Journal (I):**International Journal of Automotive Technology

The selected research articles from respective journals also provide information about various countries where biodynamics researches have been performed (Fig. 3).

Out of these countries, United Kingdom contributes maximum towards biodynamic research investigations followed by other countries.

As mentioned above, biodynamic investigations are performed by evaluating in terms of apparent mass (APMS), transmissibility (T) and vibration power absorbed (VPA) functions. As far as literature reviewed, selected studies found to contribute maximum in the form of transmissibility responses followed by apparent mass and vibration power absorbed responses. However, Vertical axis (Z) seems most prominent axis rather than fore-and-aft (x) and lateral axis (y) in order to perform biodynamic investigations whether apparent mass, transmissibility or vibration power absorbed function as shown in Fig. 4.

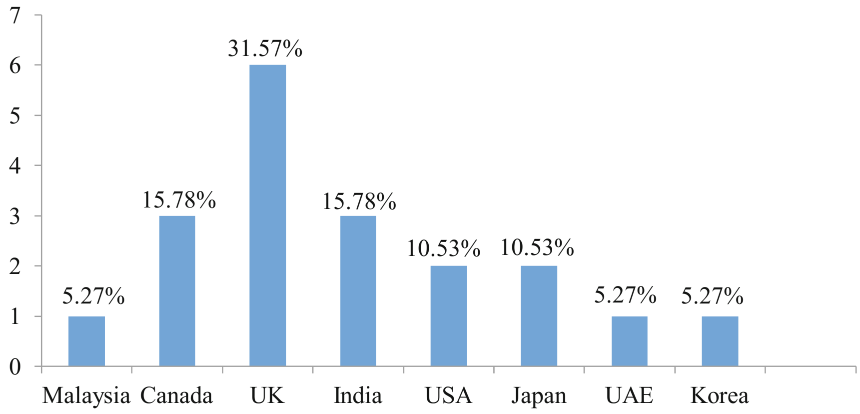

Fig. 3. Countries contribution towards biodynamic investigations

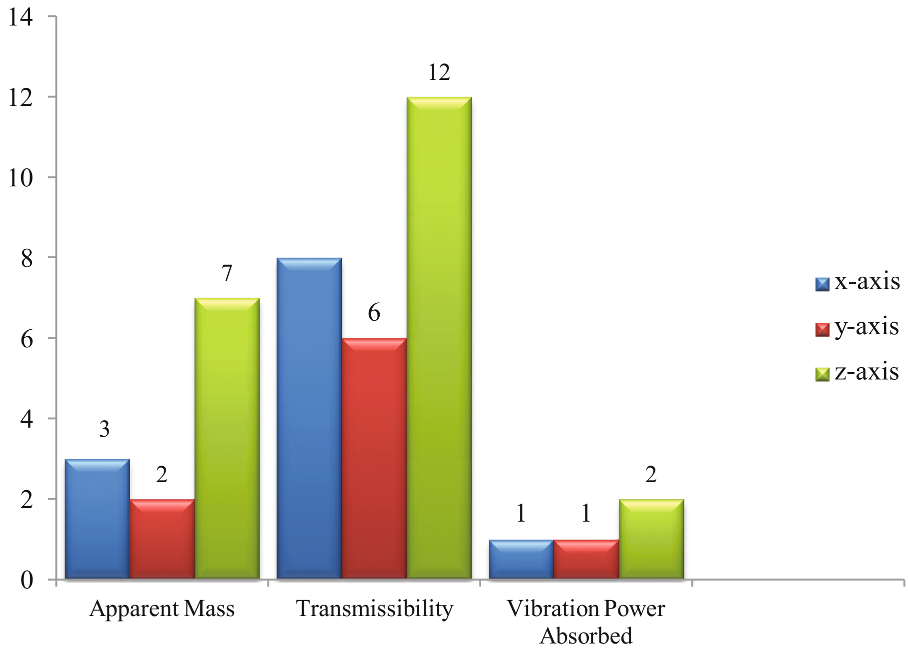

Fig. 4. Number of biodynamic function in respective axis

4 Research Potentials

This review study also tried to explore some research potentials for future researches in the field of biodynamics in order to enhance human comfort. These studies are not only limited to vehicles in fact all types of vibrating environments can be analyzed by means of such biodynamic functions. A few research opportunities have been listed as below:

- The biodynamic investigations are very much explored in Indian regions, none of study has been found to investigate apparent mass, and vibration power absorbed functions. Hence, it may provide better understanding of human response behavior under various occupations.
- Majority of research studies have been performed under controlled laboratory conditions. Moreover, results of such laboratory investigations might be compared with similar conditions under real field conditions.
- Apart from vehicles study, biodynamics investigation might also be performed in biomedical field applications.
- A detailed investigation may also require to explore the effect of fore-and-aft, lateral as well as vertical axis, as in many cases fore-and-aft and lateral observed as dominant axis as compare to vertical axis.

5 Conclusions

Present review study addressed a number of key issues that might be important to understand for further biodynamic investigations. It has been concluded that majority of such studies have been quiet popular in developed countries rather than developing such as India. However, Indian studies are limited to evaluate transmissibility function only under controlled lab setup conditions. Subsequent to simulated lab setup studies, similar investigations might be performed under real field conditions in order to observe the effect of additional factors on output responses. As per the aim of study, identified studies have not undertaken tractor-driving occupations which is quiet indispensable in agricultural field. Moreover, Punjab region in India, have been considered as food bowl of India, which might need such investigation because of higher usage of tractors while performing various agricultural activities. Therefore, study concluded a need to explore biodynamic investigations especially on Indian tractor drivers under both simulated laboratory as well as real field conditions to improve human ride comfort.

References

1. Griffin, M.J.: Handbook of Human Vibration. Academic Press, London (2012)
2. Loutridis, S., Gialamas, T., Gravalos, I., Moshou, D., Kateris, D., Xyradakis, P., Tsiropoulos, Z.: A study on the effect of electronic engine speed regulator on agricultural tractor ride vibration behavior. J. Terramech. **48**(2), 139–147 (2011)
3. International Organization for Standardization: Guide for the evaluation of human exposure to whole body vibration. ISO 2631 (1985)
4. Langer, T.H., Ebbesen, M.K., Kordestani, A.: Experimental analysis of occupational whole-body vibration exposure of agricultural tractor with large square baler. Int. J. Ind. Ergonom. **47**, 79–83 (2015)

5. Rakheja, S., Dong, R.G., Patra, S., Boileau, P.E., Marcotte, P., Warren, C.: Biodynamics of the human body under whole-body vibration: synthesis of the reported data. Int. J. Ind. Ergonom. **40**(6), 710–732 (2010)
6. Mansfield, N.J.: Impedance methods (apparent mass, driving point mechanical impedance and absorbed power) for assessment of the biomechanical response of the seated person to whole-body vibration. Ind. Health **43**(3), 378–389 (2005)
7. Toward, M.G., Griffin, M.J.: Apparent mass of the human body in the vertical direction: effect of a footrest and a steering wheel. J. Sound Vib. **329**(9), 1586–1596 (2010)
8. Toward, M.G., Griffin, M.J.: Apparent mass of the human body in the vertical direction: inter-subject variability. J. Sound Vib. **330**(4), 827–841 (2011)
9. Toward, M.G., Griffin, M.J.: The transmission of vertical vibration through seats: influence of the characteristics of the human body. J. Sound Vib. **330**(26), 6526–6543 (2011)
10. Gohari, M., Rahman, R.A., Raja, R.I., Tahmasebi, M.: A novel artificial neural network biodynamic model for prediction seated human body head acceleration in vertical direction. J. Low Freq. Noise V. A. **31**(3), 205–216 (2012)
11. Dewangan, K., Shahmir, A., Rakheja, S., Marcotte, P.: Vertical and fore-aft seat-to-head transmissibility response to vertical whole body vibration: gender and anthropometric effects. J. Low Freq. Noise V. A. **32**(1–2), 11–40 (2013)
12. Mandapuram, S., Rakheja, S., Boileau, P.E., Shangguan, W.B.: Energy absorption of seated body exposed to single and three-axis whole body vibration. J. Low Freq. Noise V. A. **34**(1), 21–38 (2015)
13. Qiu, Y., Griffin, M.J.: Modelling the fore-and-aft apparent mass of the human body and the transmissibility of seat backrests. Veh. Syst. Dyn. **49**(5), 703–722 (2011)
14. Harsha, S.P., Desta, M., Prashanth, A.S., Saran, V.H.: Measurement and bio-dynamic model development of seated human subjects exposed to low frequency vibration environment. Int. J. Veh. Noise Vib. **10**(1–2), 1–24 (2014)
15. Kumar, V., Saran, V.H.: Influence of postures and vibration magnitude on seat-to-head transmissibility during uniaxial whole body vibration exposure. Int. J. Veh. Noise Vib. **11**(2), 149–164 (2015)
16. Bhiwapurkar, M.K., Saran, V.H., Harsha, S.P.: Effects of vibration magnitude and posture on seat-to-head-transmissibility responses of seated occupants exposed to lateral vibration. Int. J. Veh. Noise Vib. **12**(1), 42–59 (2016)
17. Jonsson, P.M., Rynell, P.W., Hagberg, M., Johnson, P.W.: Comparison of whole-body vibration exposures in buses: effects and interactions of bus and seat design. Ergonmics **58**(7), 1133–1142 (2014)
18. Zhang, X., Qiu, Y., Griffin, M.J.: Developing a simplified finite element model of a car seat with occupant for predicting vibration transmissibility in the vertical direction. Ergonomics **58**(7), 1220–1231 (2015)
19. Shibata, N., Maeda, S.: Determination of backrest inclination based on biodynamic response study for prevention of low back pain. Med. Eng. Phys. **32**(6), 577–583 (2010)
20. Basri, B., Griffin, M.J.: The application of SEAT values for predicting how compliant seats with backrests influence vibration discomfort. Appl. Ergon. **45**(6), 1461–1474 (2014)
21. Mandapuram, S., Rakheja, S., Boileau, P.E., Maeda, S.: Apparent mass and head vibration transmission responses of seated body to three translational axis vibration. Int. J. Ind. Ergonom. **42**(3), 268–277 (2012)
22. Thamsuwan, O., Blood, R.P., Ching, R.P., Boyle, L., Johnson, P.W.: Whole body vibration exposures in bus drivers: a comparison between a high-floor coach and a low-floor city bus. Int. J. Ind. Ergonom. **43**(1), 9–17 (2013)

23. Nawayseh, N.: Effect of the seating condition on the transmission of vibration through the seat pan and backrest. Int. J. Ind. Ergonom. **45**, 82–90 (2015)
24. Shibata, N.: Effect of phase difference on biodynamic response of seated body to dual-axis vibration. Int. J. Ind. Ergonom. **45**, 55–63 (2015)
25. Song, J.T., Ahn, S.J., Jeong, W.B., Yoo, W.S.: Subjective absolute discomfort threshold due to idle vibration in passenger vehicles according to sitting posture. Int. J. Auto. Tech. **18**(2), 293–300 (2017)

Social and Occupational Ergonomics Applications

Self-actualization in Modern Workplaces—Time-Lagged Effects of New Job Demands and Job Resources on Motivation, Meaning and Self-efficacy at Work

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Abstract. Effects of novel job demands and matched resources on self-actualization at work were examined longitudinally (1 month) in a sample of N = 732 employees. At both measurements, cross-sectional correlations showed positive relationships between requirements for learning and self-regulation (except for temporal flexibility requirements, as hypothesized) with indicators of self-actualization (work motivation, meaning in work, occupational self-efficacy). Job resources selected to match these demands (qualification options, job autonomy, boundary control) were positively related to indicators of self-actualization. Results of longitudinal path analysis (controlled for age, sex, position, education, and self-actualization at baseline) revealed positive time-lagged effects of learning requirements on occupational self-efficacy, of qualification options on meaning in work, as well as an augmenting effect of the interaction between learning requirements and qualification options on work motivation. Due to the short measurement interval and high autocorrelation of indicators, cross-lagged effects are weak. Further limitations and implications for research and practice are discussed.

Keywords: Work design · New job demands · Job resources · Workplace learning · Self-actualization · Longitudinal study · Interaction effect

1 Introduction

1.1 Eudaimonic Living

Reflections about meaningful work and its potential for personality development date back to ancient Greek philosophers like Aristotle. He focused on ethically successful life conduct in the sense of eudaimonia, which was assumed to be gained through self-determined activities matching own capacities and virtues, “to achieve the best that is within us” [1]. Positive psychology with its focus on well-being [2] likewise refers to

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eudaimonia but was critized for higlighting rather hedonic issues like pleasure and happiness while neglecting eudaimonic prescriptions of growth and human fulfillment [1, 3]. "Eudaimonic conceptions focus on the content of one's life, and the processes involved in living well, whereas hedonic conceptions of well-being focus on a specific outcome, namely the attainment of positive affect and an absence of pain" [4, p. 140].

1.2 Self-actualization

Self-determination theory (SDT) [5] provides another fruitful framework, as it suggested motives for self-actualization and personal growth, i.e., needs for autonomy, competence, and relatedness. According to SDT, realization of valued human potential in terms of self-actualization implies characteristics that offer possibilities for learning and development of competences, options for self-regulation, and autonomy as well as social relationships in terms of cooperation and social support. Moreover, by engaging in individually meaningful endeavors at work, human potential and the "full functioning" of a person is actualized [4]—a process worthy of support by human-centered work design.

1.3 Self-actualization at Work

Within the context of work in organizations, self-actualization was propagated by human relations research [6, 7] and sociotechnical system approaches [8] to overcome monotonous tasks in Tayloristic work systems by human-centered work design [9]. Grounded in Activity Theory [10], Action Regulation Theory (ART) [11] proposed personality development as the superior goal of work design, thus bringing core criteria of eudaimonia into work analysis and work design. Likewise, both the Job Demand-Control-Support-Model [12, 13] and the Job Characteristics Model [14], accentuate aspects of learning and development at work. Both models have been synthesized into the broader framework of the differentiated Job Demands–Resources (JDR) Model of work design [15] that distinguishes between challenge and hindrance demands according to Transactional Stress Theory [16]. According to the differentiated JDR Model, challenge demands and job resources are supposed to trigger processes of motivation and learning.

1.4 Changes in Work

Today, many workplaces feature high demands for learning, self-regulation, and flexibility [17, 18] due to deregulation of labor markets, transitions towards qualified knowledge-intensive work, innovation acceleration in information and communication technologies, and transformations from standardized work to flexible or even boundariless work arrangements [19]. Such fundamental changes in the nature of work seem to correspond to growing needs and expectations for self-actualization of new generations of employees labeled "generation Y" and "digital natives" [20, 21].

A first period of research on flexible work arrangements primarily focused on the potential benefits of telework and work-time flexibility in terms of balancing life domains and reduction of work-family conflicts [22, 23], followed by a “positive psychology perspective” on processes of enrichment between work and family domains [24]. Actually, effort-recovery research seems to predominantly focus on work strain-related health impairment [25] as a steadily growing side-effect of technologically-assisted flexible work arrangements under conditions of work intensification and work extensification [18]. Currently, individual styles of boundary management to cope with role expectations and preferences and to balance life domains are studied intensely [26].

1.5 Study Aim and Hypotheses

Aim of the Study. Transcending conventional models of work design, this study investigates main and interactive effects of new job demands and matched domain-specific job resources on self-actualization at work. Novel requirements for learning, self-regulation, and work-time flexibility were matched with domain specific job resources for learning, self-regulation, and time management in order to examine longitudinally the hypothesized beneficial effects on indicators of self-actualization at work. Outcomes were derived from eudaimonic criteria in terms of motivated, meaningful, and effective activity at work [1].

Hypotheses. Our study addresses four hypotheses grounded in theoretical frameworks of Eudaimonia, ART, SDT, and the differentiated JDR-model. **(H1)** *Requirements for learning and self-regulation are (a) positively and (b) prospectively related to indicators of self-actualization at work*. Both demands address self-determined actions as means to fulfill basic psychological needs for competence and autonomy [5]. **(H2)** *Work-time flexibility requirements are less related to indicators of self-actualization at work.* Although temporal flexibility demands might also be framed as challenge demands (e.g., to develop individual time management skills), in terms of SDT, however, such situational demands should rather elicit an extrinsically motivated, instrumental behavior than a process of internalized self-actualization (first-order goals [4]. **(H3)**. *Domain-specifically matched resources for learning and self-regulation are (a) positively and (b) prospectively related to indicators of self-actualization at work.* According to the differentiated JDR-Model, job resources are supposed to support the achievement of work goals and mastering job demands. Core job resources like autonomy have consistently been found to enhance intrinsic motivation as an indicator for personality development at work [27]. **(H4)**. *An additional prospective augmenting (interaction) effect of new job demands and matched resources for learning and self-regulation on indicators of self-actualization at work is expected*. According to well-established interaction hypotheses in work design ([12, 28]) and based upon empirical evidence for beneficial interaction effects of (matched) job demands and resources on indicators of well-being at work [29, 30], we assume such augmenting effects on self-actualization will hold true for rather novel job demands and their matched resources for learning and self-regulation at work.

2 Method

2.1 Sample

The study was conducted as a longitudinal employee survey on working conditions and psychological well-being. Online questionnaires were distributed by snowball sampling; optional paper-pencil forms were available on request. With a time lag of one month after baseline measurement (T1), all respondents at baseline were invited to participate in the follow-up (T2). Complete longitudinal data sets of $N = 732$ employees were gathered that could be utilized for the analyses. 57.9% of respondents were female. Mean age was 38.9 years, ranging from 18 to 72 years. 49.7% of respondents held an university or college degree and another 20% had high school exams. 30.9% reported to be supervisors. Employees worked in very diverse economic sectors and occupations, covering a broad range of working conditions in different settings of modern work.

2.2 Measurement of New Job Demands and Matched Job Resources

New Job Demands. Novel work demands were framed as the requirements employees face in times of flexible work arrangements. Three measures of "perceived flexibility requirements" [18, 31] were selected with respect to requirements for learning, self-regulation, and time-flexibility. Based on the standard instruction "My employer expects me to …", three items each were used to operationalize *learning requirements* (e.g., "… continuously develop my abilities and skills"), *self-regulation requirements* (e.g., "… show high self-responsibility at work"), and *time-flexibility requirements* (e.g., "…be flexible with respect to working time"). All items were to be rated on a six-point response scale (1 = *definitely no*; 6 = *yes, exactly*). Cronbach's alpha (α) proved satisfying to good internal consistencies for all measures at both times of measurement (Table 1).

Matched Job Resources. Domain-specific resources to cope with the examined new job demands for learning and self-regulation were selected from an adapted universal version of the "Work Analysis Instrument for Hospitals" [32], approved in different work settings and occupations [33]. Two scales of this instrument, each subsuming three items, were used to analyze *qualification options* (e.g., "my work allows me to acquire new skills regularly") as a specific job resource matching new learning requirements, and *job autonomy* (e.g., "my work offers discretion on how to do my work") as the matching resource for self-regulation requirements at work. Finally, *boundary control* [26] was chosen as a domain-specific resource to match work-time-flexibility requirements. Comprising three items (e.g. "I control whether I have clear boundaries between my work and personal life"), the scale indicates the degree of perceived psychological control concerning separation vs. integration of work and private life domains within the scope of boundary management [26]. Items were to be rated on a five-point response scale (1 = *no, not at all*; 5 = *yes, exactly*). Alpha coefficients of the three job resources measures proved satisfactory to good internal consistency at both times of measurement (Table 1).

2.3 Measurement of Self-actualization at Work

Ryff and Singer's dimensions of psychological well-being [1] address outcomes of a life well lived, including facets of personal growth, environmental mastery, positive relationships, life purpose, self-acceptance, and autonomy. For this study, we focused on work-related dimensions of well-being, thus selecting intrinsic work motivation, meaning in work, and occupational self-efficacy as suitable theory-based motivational, cognitive, and behavioral indicators of self-actualization at work.

Intrinsic Work Motivation. The *motivational dimension* of self-actualization at work was measured by the three highest-loading items of the well-established *intrinsic work motivation* measure [34]. Items (e.g., "I feel a sense of personal satisfaction when I do this job well") were rated on a five-point response scale (1 = *no, not at all*; 5 = *yes, exactly*). Internal consistency was good (Table 1).

Meaning in Work. The *cognitive dimension* of self-actualization at work was measured by three items of an adapted *meaning in work* measure [35], focusing on aspects of meaningful work. The items (e.g., "my work fulfills me") were rated on a five-point response scale (1 = *completely disagree*; 5 = *completely agree*). Internal consistency was good to excellent (Table 1).

Occupational Self-efficacy. The *behavioral dimension* of self-actualization at work was measured by three items of the *occupational self-efficacy* measure [36]. Items (e.g., "I feel prepared to meet most of the demands in my job") were rated on a five-point response scale (1 = *completely disagree*; 5 = *completely agree*). The scale exhibited good internal consistency (Table 1).

3 Results

3.1 Structural Validity and Descriptives

To examine the structural validity of our measurement model, confirmatory factor analysis (AMOS 23.0) was applied. Results supported the hypothesized nine-factor model of three factors each for job demands, job resources, and self-actualization (χ^2 = 827.085, df = 288, p < .001, χ^2/df = 2.872, IFI = .938, TLI = .917, CFI = .937, RMSEA [90%-CI] = .051 [.047, .055], CN = 291 [p < .05]). This model also fit the data better than alternative models (e.g., demands and resources grouped in three factors of learning, self-regulation, time-flexibility; one-factor model).

Descriptive results (Table 1) showed rather high levels of perceived employer requirements for self-regulation as well as moderate to high levels of requirements for learning and time-flexibility requirements, indicating that employees were confronted with such novel job demands on a regular basis and to a relevant extent. While qualification options and boundary control showed rather high values, job autonomy was less pronounced. Intrinsic work motivation and meaning in work also exhibited rather high levels in our sample, whereas occupational self-efficacy was reported to a moderately high degree.

Table 1. Descriptive statistics.

Measure	Items	α (T1/T2)	T1: *M* (*SD*)	T2: *M* (*SD*)	r_{tt}
New job demands					
Learning requirements	3	(.82, .85)	4.51 (1.11)	4.45 (1.09)	.76
Self-regulation requirements	3	(.70, .77)	4.94 (0.80)	4.81 (0.83)	.68
Time-flexibility requirements	3	(.73, .77)	4.46 (1.11)	4.35 (1.10)	.69
Job resources					
Qualification options	3	(.72, .77)	3.88 (0.84)	3.79 (0.83)	.75
Job autonomy	3	(.79, .84)	3.52 (0.92)	3.51 (0.91)	.80
Boundary control	3	(.76, .78)	3.81 (0.94)	3.83 (0.89)	.49
Self-actualization at work					
Intrinsic work motivation	3	(.80, .82)	4.27 (0.69)	4.23 (0.68)	.72
Meaning in work	3	(.87, .90)	3.97 (0.87)	3.93 (0.90)	.86
Occupational self-efficacy	3	(.80, .80)	3.73 (0.65)	3.76 (0.63)	.70

α = Cronbach's alpha; r_{tt} = stability coefficient (test-retest reliability).

3.2 Correlations

Intercorrelations among predictors (novel job demands and matched resources) at T1/T2 ranged between $r = -.08/-.12$ and $r = .41/.49$. Stability coefficients of predictors (autocorrelations between T1 and T2; Table 1) varied between $r = .49$ and $r = .76$. All indicators of self-actualization showed high stability.

Examination of zero-order correlations at baseline revealed that age and leadership position were positively associated with meaning in work and occupational self-efficacy (between $r = .11$ and $r = .14$; $p < .01$). Men reported higher occupational self-efficacy than women ($r = .19$; $p < .01$). Whereas time-flexibility requirements were unrelated to work motivation and meaning in work (between $r = .05$ and $r = .06$; *n.s.*) and were only weakly associated with occupational self-efficacy ($r = .08$; $p < .10$), learning and self-regulation requirements as well as all matched job resources showed highly significant correlations with indicators of self-actualization (between $r = 13$ and $r = .44$; $p < .01$). These findings were quite consistent across measurement points, providing initial support for H1a and H2.

3.3 Time-Lagged Main and Interaction Effects

A longitudinal path model tested for main and pairwise matched interactive effects of job demands and job resources (learning requirements and learning opportunities; self-regulation requirements and job autonomy; time-flexibility requirements and boundary control) at T1 on the indicators of self-actualization at work at T2. Age, sex, education, position, as well as outcomes were controlled for at baseline. We thereby examined the changes in self-actualization at work as predicted by antecedent novel job demands and matched resources. This hypothesized time-lagged path model (Table 2) showed an acceptable overall fit with the data ($\chi^2 = 36.209$, $df = 6$, $p < .001$,

Table 2. Path coefficients (β) of time-lagged relationships between novel job demands and matched job resources (T1) and indicators of self-actualization (T2) at work (N = 732).

Parameter	Intrinsic work motivation T2	Meaning in work T2	Occupational self-efficacy T2
Age T1	.013	.040*	.005
Sex T1	−.034	.012	.110**
Education T1	−.005	.009	.009
Position T1	−.043	−.001	.035
Intrinsic work motivation T1	.685***	–	–
Meaning in work T1	–	.799***	–
Occupational self-efficacy T1	–	–	.625***
Learning requirements T1	.060*	.033	.084***
Self-regulation requirements T1	.030	.002	−.003
Temporal-flexibility requirements T1	.040	.016	.051*
Qualification options T1	.030	.067**	−.035
Job autonomy T1	.017	.003	.098***
Boundary control T1	.026	.014	.052*
Learning requirements x qualification options T1	.065**	.012	.053*
Self-regulation requirements x job autonomy T1	.028	−.032	.035
Temporal-flexibility requirements x boundary control T1	−.018	.003	−.017
R^2	.525	.731	.523

**** $p < .01$, ** $p < .05$, * $p < .10$.*

cχ^2/df = 6.035, IFI = .992, TLI = .745, CFI = .992, RMSEA [90%-CI] = .083 [.058, .110], CN = 255 [$p < .05$]).

The model was dominated by strong auto-regressive paths between T1 and T2 measures of work motivation (ß = .685; $p < .01$), meaning in work (ß = .799; $p < .01$), and occupational self-efficacy (ß = .625; $p < .01$). Learning requirements exerted a marginal time-lagged effect on work motivation (ß = .060; $p < .10$) and a more substantial effect on occupational self-efficacy (ß = .084; $p < .01$). Further, occupational self-efficacy was influenced by job control (ß = .098; $p < .01$), gender (ß = .110; $p < .01$), and, to a lesser extent, flexibility requirements (ß = .051; $p < .10$), and boundary control (ß = .052; $p < .10$). Qualification options contributed significantly to the prediction of meaning in work (ß = .067; $p < .05$). Age predicted meaning in work to a marginal extent (ß = .040; $p < .10$). The matched interaction of learning requirements and learning resources showed a significant time-lagged augmenting effect on intrinsic work motivation (ß = .065; $p < .05$) and a comparable, but marginal influence on occupational self-efficacy (ß = .053; $p < .10$).

4 Discussion

Summary of the Study. This study extends traditional models of work design by focusing on rather new job demands of learning, self-regulation, and time-flexibility perceived by 732 employees in contemporary work in diverse economic sectors and a broad range of occupations. Referring to differentiated models of job demands and job resources [15] as well as principles of matched job conditions [29], job characteristics suitable to cope with requirements for learning (qualification options), self-regulation (job autonomy), and time-flexibility (boundary control) were selected as domain-specifically matched job resources.

Beyond the well-known negative side-effects of contemporary flexible work systems [18, 37], our study aimed to examine main and interactive time-lagged effects of novel demands and matched resources on aspects of self-actualization at work, indicative of personality development of employees. Applying theories of eudaimonia and self-determination, three indicators for self-actualization at work were established. We focused on work-related dimensions of eudaimonic well-being, represented by intrinsic work motivation, meaning in work, and occupational self-efficacy as motivational, cognitive, and behavioral indicators of self-actualization at work.

Findings in a Nutshell. The results of the study lend support to the hypothesized time-lagged effects of both (a) learning demands and learning resources, and (b) self-regulation demands and job autonomy on self-actualization. In contrast, time-flexibility demands did not predict self-actualization at work.

Cross-Sectional Results. Patterns of cross-sectional results at both times of measurement revealed that requirements for learning and self-regulation as well as learning opportunities and job control but not requirements for time-flexibility at work were positively associated with motivational (intrinsic work motivation), cognitive (meaning in work), and behavioral (occupational self-efficacy) indicators of self-actualization at work. A distinction between extrinsic (work context) and intrinsic factors (work content) might explain such differences, according to assumptions of self-determination theory [5].

Longitudinal Results. Longitudinal analyses revealed mixed results, supporting at least some of the expected positive dynamics. Beside several main effects, a notable time-lagged augmenting interactive effect of requirements and resources for learning on self-actualization at work was found. This underscores the importance of matching domain-specific demands and supplies for personal development at work, which means that self-actualizing work design should seek to pair novel job demands for learning with corresponding domain-specific resources like qualification options [38] in order to harness exceptionally beneficial effects.

Limitations. The rather short measurement interval of one month and the associated high auto-regressions of indicators of self-actualization might have impeded the detection of additional or stronger effects of job conditions under study on self-actualization. In seeking to explain time-lagged effects of novel job demands and matched resources on self-actualization at work more precisely, future studies should vary time frames between baseline and follow-up [39].

With respect to novel job stressors like work intensification or acceleration [40, 41] harmful effects on employee health should be acknowledged. Additionally, social needs for relatedness should be accounted for with a focus on new cooperation requirements and matching social resources.

Conclusion. Results of our study will suggest: To promote learning and self-actualization at work, more attention should be paid to specifically matching configurations of job demands and job resources. Work design needs to integrate eudaimonic and self-determined striving into new psychosocial working conditions by balancing requirements and supplies for learning and self-regulation.

References

1. Ryff, C.D., Singer, B.H.: Know thyself and become what you are: a eudaimonic approach to psychological well-being. J. Happiness Stud. **9**, 13–39 (2008)
2. Seligman, M.E.P., Csikszentmihalyi, M.: Positive psychology: an introduction. Am. Psychol. **55**, 5–14 (2000)
3. Ryan, R.M., Deci, E.L.: On happiness and human potentials: a review of research on hedonic and eudaimonic well-being. Annu. Rev. Psychol. **52**, 141–166 (2001)
4. Ryan, R.M., Huta, V., Deci, E.L.: Living well: a self-determination theory perspective on eudaimonia. J. Happiness Stud. **9**, 139–170 (2008)
5. Deci, E.L., Ryan, R.M.: The “What” and “Why” of goal pursuits: human needs and the self-determination of behavior. Psychol. Inq. **11**, 227–268 (2000)
6. McGregor, D.: The Human Side of Enterprise. McGraw-Hill, New York (1960)
7. Maslow, A.H.: Toward a Psychology of Being. Van Nostrand, Princeton (1962)
8. Emery, F.E., Thorsrud, E.: Form and Content in Industrial Democracy: Some Experiences from Norway and Other European Countries. Van Gorcum, Assen (1969)
9. Ulich, E.: Arbeitspsychologie, 7th edn. Schäffer-Poeschel, Stuttgart (2011)
10. Leontjew, A.N.: Tätigkeit, Bewusstsein, Persönlichkeit. Klett, Stuttgart (1977)
11. Hacker, W.: Action regulation theory: a practical tool for the design of modern work processes? Eur. J. Work Organ. Psychol. **12**, 105–130 (2003)
12. Karasek, R.: Job demands, job decision latitude, and mental strain: implications for job redesign. Admin. Sci. Q. **24**, 285–308 (1979)
13. Johnson, J.V., Hall, E.M.: Job strain, work place social support, and cardiovascular disease: a cross-sectional study of a random sample of the Swedish working population. Am. J. Public Health **78**, 1336–1342 (1988)
14. Hackman, J.R., Oldham, G.R.: Development of the job diagnostic survey. J. Appl. Psychol. **60**, 159–170 (1975)
15. Bakker, A.B., Demerouti, E., Sanz-Vergel, A.I.: Burnout and work engagement: the JD–R approach. Annu. Rev. Organ. Psychol. Organ. Behav. **1**, 389–411 (2014)
16. Lazarus, R.S., Folkman, S.: Stress, Appraisal, and Coping. Springer, New York (1984)

17. Gerdenitsch, C., Kubicek, B., Korunka, C.: Control in flexible working arrangements: when freedom becomes duty. J. Pers. Psychol. **14**, 61–69 (2015)
18. Höge, T., Hornung, S.: Perceived flexibility requirements: exploring mediating mechanisms in positive and negative effects on worker well-being. Econ. Ind. Democracy **36**, 407–430 (2015)
19. Cascio, W.F., Montealegre, R.: How Technology is Changing Work and Organizations. Annu. Rev. Organ. Psychol. Organ. Behav. **3**, 349–375 (2016)
20. Howe, N., Strauss, W.: Millennials Rising: The Next Great Generation. Vintage Books, New York (2000)
21. Ng, E.S., Schweitzer, L., Lyons, S.T.: New generation, great expectations: a field study of the millennial generation. J. Bus. Psychol. **25**, 281–292 (2010)
22. Greenhaus, J.H., Beutell, N.J.: Sources of conflict between work and family roles. Acad. Manag. Rev. **10**, 76–88 (1985)
23. Byron, K.: A meta-analytic review of work-family conflict and its antecedents. J. Vocat. Behav. **67**, 169–198 (2005)
24. Greenhaus, J.H., Powell, G.N.: When work and family are allies: a theory of work-family enrichment. Acad. Manag. Rev. **31**, 72–92 (2006)
25. Sonnentag, S., Binnewies, C., Mojza, E.J.: Staying well and engaged when demands are high: the role of psychological detachment. J. Appl. Psychol. **95**, 965–976 (2010)
26. Kossek, E.E., Ruderman, M.N., Braddy, P.W., Hannum, K.M.: Work-nonwork boundary management profiles: a person-centered approach. J. Vocat. Behav. **81**, 112–128 (2012)
27. Fried, Y., Ferris, G.R.: The validity of the job characteristics model: a review and meta-analysis. Pers. Psychol. **40**, 287–322 (1987)
28. Bakker, A.B., Hakanen, J.J., Demerouti, E., Xanthopoulou, D.: Job resources boost work engagement, particularly when job demands are high. J. Educ. Psychol. **99**, 274–284 (2007)
29. De Jonge, J., Dormann, C., Van den Tooren, M.: The demand-induced strain compensation model: renewed theoretical considerations and empirical evidence. In: Näswall, K., Hellgren, J., Sverke, M. (eds.) The Individual in the Changing Working Life, pp. 67–87. Cambridge University Press, New York (2008)
30. Hu, Q., Schaufeli, W.B., Taris, T.W.: The job demands-resources model: an analysis of additive and joint effects of demands and resources. J. Vocat. Behav. **79**, 181–190 (2011)
31. Höge, T.: Perceived flexibility requirements at work and the entreployee work-orientation: concept and measurement. Psychol. Everyday Act. **4**, 3–21 (2011)
32. Büssing, A., Glaser, J.: Das Tätigkeits- und Arbeitsanalyseverfahren für das Krankenhaus – Selbstbeobachtungsversion (TAA-KH-S). Hogrefe, Göttingen (2002)
33. Glaser, J., Seubert, C., Hornung, S., Herbig, B.: Learning demands, work-related resources, and job stressors and their relationships to creative performance and health. J. Pers. Psychol. **14**, 37–48 (2015)
34. Warr, P., Cook, J., Wall, T.: Scales for the measurement of some work attitudes and aspects of psychological well-being. J. Occup. Psychol. **52**, 129–148 (1979)
35. Schnell, T., Höge, T., Pollet, E.: Predicting meaning in work: theory, data, implications. J. Posit. Psychol. **8**, 543–554 (2013)
36. Schyns, B., von Collani, G.: A new occupational self-efficacy scale and its relation to personality constructs and organizational variables. Eur. J. Work Organ. Psychol. **11**, 219–241 (2002)
37. Glaser, J., Palm, E.: Flexible und entgrenzte Arbeit – Fluch oder Segen für die psychische Gesundheit? Wirtschaftspsychologie **44**, 82–98 (2016)
38. Taris, T., Kompier, M.: Job demands, job control and learning behavior: review and research agenda. In: Antoniou, A., Cooper, C. (eds.) Research Companion to Organizational Health Psychology, pp. 32–150. Edward Elgar, Cheltenham (2005)

39. Dormann, C., Griffin, M.A.: Optimal time lags in panel studies. Psychol. Methods **20**, 489–505 (2015)
40. Rosa, H.: Social Acceleration: A New Theory of Modernity. Columbia University Press, New York (2013)
41. Kubicek, B., Paškvan, M., Korunka, C.: Development and validation of an instrument for assessing job demands arising from accelerated change: the intensification of job demands scale (IDS). Eur. J. Work Organ. Psychol. **24**, 898–913 (2015)

Ergonomics Contribution in the RTW of Workers After Work-Related Musculoskeletal Disorders

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Abstract. The objective of this paper is to provide an overview of the use of ergonomic intervention (EI) in rehabilitation programs for workers with compensated work related musculoskeletal disorders (WRMSDs), aimed to achieve sustainable return-to-work (RTW). Groups of terms allow searching 10 databases. Thirty-one articles were selected. Recurrent themes were identified and content analyzed to describe the EI. The results support the effectiveness of the rehabilitation programs with ergonomic component in achieving sustainable RTW for workers with WRMSDs. However, the content of EIs and the way to conduct it differ according to the definition of ergonomics and the approach used. The management of the RTW process seems still be challenging in terms of training the major actors in how to better modify work and workplace. A comprehensive ergonomic framework seems needed to guide rehabilitation professionals in using ergonomics to improve the RTW sustainability by ergonomic changes and modifications in the workplace.

Keywords: Ergonomics · Work rehabilitation · Return-to Work · Intervention

1 Introduction

Work related musculoskeletal disorders (WRMSDs) are among the most common causes of disability in many industrialized countries. WRMSDs generate important personal and societal consequences (such as increased health care needs, worker compensation and productivity costs for employers, etc.).

Workplace rehabilitation intervention is reported to be successful in people with WRMSDs when they focus specifically on return to work (RTW) factors related to the workplace [1–4]. Workplace rehabilitation programs often include ergonomic intervention (EI), focusing on interfacing between workers and their work environments in order to optimize employee health, safety, performance, and productivity. Numerous research papers indicate reductions of workplace injuries following an EI, which seems effective in reducing the physical, cognitive, psychosocial and other job demands, increasing productivity [5, 6]. Also, there is growing support in the literature for the use of ergonomics within work rehabilitation programs, especially when the specificity of workplace parameters is taken into account and the focus is on RTW, work tasks being

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adapted accordingly. Nevertheless, little is known about what EI implies, how it works and why it leads to such positive outcomes. Thus, the objective of this article is to provide an overview of the “ergonomics” component of work rehabilitation programs, and to describe the literature pertaining to the contribution of EI in achieving a sustainable RTW.

2 Methodology

To explore the conceptualization of EIs as a main component of rehabilitation programs, a scoping review [7] was performed. Firstly, we conducted a systematic search of ten databases for rehabilitation studies of musculoskeletal disorders between January 2000 and December 2015: Ergonomics Abstracts Online, NIOSH, INRS-Bibliographie, CISDOC, HSELINE, Pascal, Canadiana, PsychINFO, Francis, MEDLINE. The search strategy combined three groups of terms (‘work rehabilitation’, ‘musculoskeletal’, and ‘ergonomic intervention’) using an “AND” connector. Secondly, after eliminating duplicates from a total of 1564 references retrieved, the pertinence and the quality of the articles were evaluated. Inclusion criteria (availability of the abstract, English or French language, publication in peer-reviewed journals and rehabilitation or RTW population) and exclusion criteria (primary prevention, clinical variables and outcomes only, protocols not followed by the original study, theoretical books’ chapters) helped us select relevant articles. Two independent reviewers carried out the selection of the articles, decisions based on inter-judge agreement. Content analyses were conducted in order to describe how ergonomics intervenes in the rehabilitation programs focusing on RTW. A grid using informational categories was created in order to describe the selected studies: objective, design, population/sampling, types of WRMSDs, stage of injury, descriptive content of the EI, authors’ perspective on the role of ergonomics in the rehabilitation process, interaction with disciplines other than ergonomics, measures, outcomes, recommendations, and needs for future research.

3 Results

3.1 Description of the Article Reviewed

Out of the 1176 references retrieved, 31 articles met the eligibility criteria: 11 literature reviews and 20 articles reporting on one or more empirical studies. The articles originated frequently from Scandinavian countries, Finland, the Netherlands, USA, Canada and Australia. Studies focus on generic disability, related to different musculoskeletal disorders (low back pain, upper extremity disorders, neck, rheumatoid arthritis or osteoarthritis, whiplash-associated disorders).

Overall, systematic literature reviews focus on the effectiveness of workplace rehabilitation and RTW programs including an EI component [1, 8–11]. They also investigate the evidence about the effectiveness of workplace–based strategies intervention in supporting sustainable RTW [12–14] or describe precisely the EI [15–17].

The empirical studies evaluate the efficacy of particular workplace programs or describe an ergonomic component of intervention in the RTW process [1, 2, 18–23].

3.2 Ergonomic Contribution

Types of Intervention. Effective workplace rehabilitation programs include participatory ergonomics [11, 14], ergonomic worksite visits [13], ergonomic assessments [10], adaptation of job tasks and working hours [11, 14], job evaluation [4, 14], workplace education or training in ergonomics [4, 9], (re)design of workplace, aids or tools [8], adjustments (improved leg room under the desk, alternative keyboard, adjustable chair, forearm supports, ergonomic keyboards, ergonomic mice, exercise/rest) [4, 8, 9, 12, 14].

Generally, the authors argue for the necessity of EI and present some evidence of the usefulness of EI in adapting the work environment to respect the particular needs of employees with disabilities [2, 22, 24, 25]. Even if lone the use of EI has not been shown to have a significant effect on the incidence or the prevalence of the rates of disorders, the potential improvement in work relationship through the EI, is an value added by itself [25]. It can improve the worker's level of comfort and its ability to work productively, which can theoretically contribute to a multimodal intervention's positive effect [2, 12, 22, 24, 25].

EIs address different dimensions of the workplace: technical (e.g. furniture, computer, equipment), organizational (e.g. tasks, working hours and duration), individual (e.g. training, journey to and from work, rehabilitation, work/life balance, psychological follow-up), worker's general relation to the work activity (e.g. their difficulties, their skills, their future) and to the workstation (e.g. activity, movements, cooperation with colleagues).

Approaches. Occupational therapists or ergonomists act as experts for EI. The specialist's role when EI is part of a rehabilitation program consists in counselling the rehabilitation team for the suitable changes for facilitating the RTW of the worker. In the case of an EI alone, the ergonomist, after doing an ergonomic evaluation of risk factors at the workplace, recommend to the organization the needed changes in order to help with the RTW.

Participative ergonomics consist in consulting workers in order to identify problems, elaborate appropriate solutions for the RTW and implant transformations in the workplace, and follow-up [3, 24–27]. For each injured worker, a group is formed that included an ergonomist (process leader), the injured worker, the worker's supervisor, and if possible other stakeholders. After observation of the worker's tasks by the ergonomist, the worker and the supervisor ranked obstacles for RTW independently. Following this, in a meeting of the group to brainstorm and discuss about all possible solutions for the obstacles ranked highest. The aim was to achieve consensus regarding feasible solutions. Finally, a short communication form exchanged between the occupational professional and the worker's general practitioner prevents conflicting advises to the worker in the return-to-work process.

Only a few studies use ergonomics as an investigative approach to apprehend the real activity of the worker before considering dynamic solutions [16, 23, 28].

The ergonomic analysis of work compares and contrasts the activities assigned to workers with the way they do them by observing the strategies used by the workers to respond to the demands of the task. After a "primary analysis" of the feasibility of an intervention in the workplace, a first contact between the company manager and the ergonomist is made following the worker's physician's go-ahead. If the manager agrees to the ergonomic procedure, the EI includes the following phases: analyzing the demand, conducting the diagnostic aiming to introduce the submitted inquiry by activating the company players, elaborating courses of action, presenting the diagnostic to the company, elaborating the specifications requirements and preparing contingencies.

Assessment. Ergonomic worksite visits and assessments consist in ergonomic analyses conducted by a specialist with the active participation of the injured employee and, when possible, the employee's supervisor [28]. Ergonomic assessment is a useful method for balancing jobs and human capabilities, conveying the need to understand the nature of a work activity in order to make adequate adjustments accounting for changes in the worker's capacities [10].

Authors also insist on the necessity of job evaluation, including listings with descriptions of tasks, tools and equipment, and their effects on the biomechanical, cognitive, emotional and behavioral performance demands on the jobholder. The main goal of the evaluation is to identify remediable physical stressors and propose feasible engineering or administrative solutions that would reduce physical and psychosocial stressors. As a result, appropriate solutions adapted to the employee's capacity are planned, and a personalized schedule for the gradual increase in workload and follow-up is fashioned for the employee returning to work.

In the studies reviewed, ergonomic assessments predominantly include the evaluation and diminishing of physical risks according to the functional capacities of the worker returning to work [15, 19, 22, 27, 29–34]. Some authors broaden their analyses from job risk factor evaluation to other aspects of work – such worker's skills, teamwork, equipment, organization [17, 24–26].

Training. A key strategy leading to the facilitation of RTW consists in training to improve ergonomic competencies of case managers coming from insurance agencies, as well as those of clinical coordinators, supervisors or employer representatives, union representatives. Successful temporary or transitional work accommodation strategies depend on different actors' ergonomic competencies in problem solving, worksite ergonomic assessment, job accommodation process and communication with the workers and other stakeholders [10, 20, 27, 32, 34].

Tools. Ergonomic tools assist health professionals in establishing an adequate fit between work demands and the workers' capabilities [22, 30, 31, 33, 34]. Ergonomic tools are often incorporated in training programs or interventions in order to identify risk factors for specific conditions [1, 3, 23, 28, 29, 33]. They also seem suitable when identifying ergonomic risk factors, determining potential solutions, and appropriate adjustments [15, 19, 22, 30, 34].

4 Discussion

This article aimed to provide an overview of EI's contribution to the achievement of a sustainable and safe RTW. Explicit definitions of the concept of ergonomics in rehabilitation were rare in the literature reviewed. However, implicitly, many authors adopt the IEA definition of ergonomics highlighting the multiple domains of possible changes in workplace. Through the consideration of the descriptions of ergonomic approaches in the articles reviewed, it appears that ergonomics shares the main goal of work rehabilitation programs for matching the capacities of workers with their job demands.

Overall, the findings point to the effectiveness and utility of EI for workers with MSDs in helping the achievement of a safe and durable RTW of workers with WRMDs. However, differences exist between the different types of intervention and approaches of solutions. These differences seem rooted into the conceptual framework of the ergonomics, whether the definition limits itself to the evaluation of risks and the prescription of solutions, or includes appropriate work analysis in order to develop solutions with the participation of all the actors involved in the RTW.

Programs that focus on ergonomic evaluation of risk generally do not involve the workers in the development of the solution. Moreover, an ergonomist or a team of occupational professionals performed the assessment through rigid tools, mismatching the dynamic of changes of the workplace intervention. The development of solutions relies on experts' recommendations for counteracting risks and considers the context only insofar as the injured worker and the supervisor are consulted about the necessary changes for thwarting the risks.

On the other hand, interventions that focus on ergonomic analysis of work involve workers and other significant actors in the development and implementation of changes in the workplace. In fact, the injured worker and the supervisor participate in all the stages: assessment and risk evaluation, analysis of the actual activity leading to the proposal of solutions. However, whether the ergonomic program adopts an expert, a consultative or a participative approach is conditional to the company management and the supervisor's willingness to participate actively and involve workers in the process.

Future research need to empower rehabilitation professionals with a framework to guide practice efforts in the area of ergonomic intervention [35]. Such frameworks should be constructive or developmental, asserting that ergonomics should emphasize on employee development in terms of knowledge and skills and optimize collective activities, address psychosocial and organizational aspects of work through dynamic process, design and developmental instruments, prevention of musculoskeletal disorders, project design, and other types of ergonomic analyses [36–38]. Moreover, such frameworks cannot limit the ergonomics with a static view of adaptation, a view that would restrict its goal to designing systems that are suited to work as it is defined at a certain point in time, to workers as they are at a particular moment, and to organizations as they operate here and now [38]. More than in others fields of application, ergonomics - as a part of a rehabilitation program or as an intervention itself aiming to improve RTW - should emphasize on setting up situations of action that lead to increased success and to the acquisition or construction of know-how and skills [39].

The integration of such approaches in workplace rehabilitation can have a beneficial impact of the RTW and its sustainability.

5 Conclusion

Overall, the results support the utility of EIs in the rehabilitation programs aimed at achieving sustainable RTW for workers with musculoskeletal disorders. However, the content of EIs used differs according to their objectives and to the implicit definition of ergonomics given by the authors. Management of the RTW process of workers with occupational disorders often poses challenges in terms of how to better modify work and workplaces as a component of the workplace accommodation and adjustment process. A comprehensive ergonomic framework seems needed to guide occupational rehabilitation professionals in using ergonomics to improve the quality and the sustainability of the ergonomic changes and modifications in the workplace.

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References

1. Durand, M.-J., Berthelette, D., Loisel, P., Imbeau, D.: Validation of the program impact theory of a work rehabilitation program. Work J. Prev. Assess. Rehabil. **42**(4), 495–505 (2012)
2. Franche, R.L., Severin, C.N., Hogg-Johnson, S., Côté, P., Vidmar, M., Lee, H.: The impact of early workplace-based return-to-work strategies on work absence duration: a 6-month longitudinal study following an occupational musculoskeletal injury. J. Occup. Environ. Med. **49**(9), 960–974 (2007)
3. van Beurden, K.M., Vermeulen, S.J., Anema, J.R., van der Beek, A.J.: A participatory return-to-work program for temporary agency workers and unemployed workers sick-listed due to musculoskeletal disorders: a process evaluation alongside a randomized controlled trial. J. Occup. Rehabil. **22**(1), 127–140 (2012)
4. Varatharajan, S., Cote, P., Shearer, H.M., Loisel, P., Wong, J.J., Southerst, D., Yu, H., Randhawa, K., Sutton, D., van der Velde, G., Mior, S., Caroll, L.J., Jacobs, C., Taylor-Vaisey, A.: Are work disability prevention interventions effective for the management of neck pain or upper extremity disorders? a systematic review by the ontario protocol for traffic injury management (OPTIMa) collaboration. J. Occup. Rehabil. **24**(4), 692–708 (2014)
5. Cole, D., Rivilis, I., Van Eerd, D., Cullen, K., Irvin, E., Kramer, D.: Effectiveness of Participatory Ergonomic Interventions: A Systematic Review. Institute for Work & Health, Toronto (2005)
6. Rivilis, I., Van Eerd, D., Cullen, K., Cole, D.C., Irvin, E., Tyson, J., Mahood, Q.: Effectiveness of participatory ergonomic interventions on health outcomes: a systematic review. Appl. Ergonomics **39**(3), 342–358 (2008)

7. Arksey, H., O'Malley, L.: Scoping studies: towards a methodological framework. Int. J. Soc. Res. Methodol. **8**(1), 19–32 (2005)
8. Elders, L.A.M., van der Beek, A.J., Burdorf, A.: Return to work after sickness absence due to back disorders – a systematic review on intervention strategies. Int. Arch. Occup. Environ. Health **73**(5), 339–348 (2000)
9. Goodman, G., Kovach, L., Fisher, A., Elsesser, E., Bobinski, D., Hansen, J.: Effective interventions for cumulative trauma disorders of the upper extremity in computer users: practice models based on systematic review. Work **42**(1), 153–172 (2012). (Reading, Mass.)
10. Shaw, W.S., Hong, Q.N., Pransky, G., Loisel, P.: A literature review describing the role of return-to-work coordinators in trial programs and interventions designed to prevent workplace disability. J. Occup. Rehabil. **18**(1), 2–15 (2008)
11. Verhagen, A.P., Bierma-Zeinstra, S.M., Burdorf, A., Stynes, S.M., de Vet, H.C., Koes, B. W.: Conservative interventions for treating work-related complaints of the arm, neck or shoulder in adults. Cochrane Database Syst. Rev. (12) (2013)
12. Burton, A.K., Kendall, N.A.S., Pearce, B.G., Birrell, L.N., Bainbridge, L.: Management of work-relevant upper limb disorders: a review. Occup. Med. (Lond.) **59**(1), 44–52 (2009)
13. Franche, R.L., Cullen, K., Clarke, J., Irvin, E., Sinclair, S., Frank, J.: Workplace-based return-to-work interventions: a systematic review of the quantitative literature. J. Occup. Rehabil. **15**(4), 607–631 (2005)
14. Williams, R.M., Westmorland, M.G., Lin, C.A., Schmuck, G., Creen, M.: Effectiveness of workplace rehabilitation interventions in the treatment of work-related low back pain: a systematic review. Disabil. Rehabil. **29**(8), 607–624 (2007)
15. Allaire, S.J., Backman, C.L., Alheresh, R., Baker, N.A.: Ergonomic intervention for employed persons with Rheumatic conditions. Work **46**(3), 355–361 (2013). (Reading, Mass.)
16. Bourmaud, G., Retaux, X.: Review of practices for keeping people with disabilities in employment: moving beyond the concept of compensation to implement a developmental approach. Work J. Prev. Assess. Rehabil. **41**, 4699–4708 (2012)
17. Faucett, J., McCarthy, D.: Chronic pain in the workplace. Nurs. Clin. N. Am. **38**(3), 169 (2003)
18. Bendix, T., Bendix, A., Labriola, M., Haestrup, C., Ebbehoj, N.: Functional restoration versus outpatient physical training in chronic low back pain: a randomized comparative study. Spine **25**(19), 2494–2500 (2000)
19. Calvo-Cerrada, B., Martinez, J.M., Dalmau, A.: Adoption of preventive measures after returning to work among workers affected by De Quervain's Tenosynovitis. J. Occup. Rehabil. **22**(4), 579–588 (2012)
20. Shaw, W.S., Robertson, M.M., McLellan, R.K., Verma, S., Pransky, G.: A controlled case study of supervisor training to optimize response to injury in the food processing industry. Work **26**(2), 107–114 (2006)
21. Arnetz, B.B., Sjogren, B., Rydehn, B., Meisel, R.: Early workplace intervention for employees with musculoskeletal-related absenteeism: a prospective controlled intervention study. J. Occup. Environ. Med. **45**(5), 499–506 (2003)
22. Baldwin, D., Johnstone, B., Ge, B., Hewett, J., Smith, M., Sharp, G.: Randomized prospective study of a workplace ergonomic intervention for individuals with Rheumatoid Arthritis and Osteoarthritis. Arthritis Care Res. **64**(10), 1527–1535 (2012)
23. Bontoux, L., Roquelaure, Y., Billabert, C., Dubus, V., Sancho, P.O., Colin, D., Brami, L., Moisan, S., Fanello, S., Penneau-Fontbonne, D., Richard, I.: Prospective study of the outcome at one year of patients with chronic low back pain in a program of intensive functional restoration and ergonomic intervention. Fact. Predicting Return Work Annales de réadaptation et de médecine physique **47**(8), 563–572 (2004)

24. Anema, J.R., Cuelenaere, B., Van der Beek, A.J., Knol, D.L., de Vet, H.C., Van Mechelen, W.: The effectiveness of ergonomic interventions on return-to-work after low back pain; a prospective two-year cohort study in six countries on low back pain patients sicklisted for 3–4 months. Occup. Environ. Med. **61**(4), 289–294 (2004)
25. Loisel, P., Gosselin, L., Durand, P., Lemaire, J., Poitras, S., Abenhaim, L.: Implementation of a participatory ergonomics program in the rehabilitation of workers suffering from subacute back pain. Appl. Ergonomics **32**(1), 53–60 (2001)
26. Anema, J.R., Steenstra, I.A., Urlings, I.J.M., Bongers, P.M., de Vroome, E.M., van Mechelen, W.: Participatory ergonomics as a return-to-work intervention: a future challenge? Am. J. Ind. Med. **44**(3), 273–281 (2003)
27. Shaw, W.S., Feuerstein, M., Lincoln, A.E., Miller, V.I., Wood, P.M.: Case management services for work related upper extremity disorders. In: Integrating Workplace Accommodation and Problem Solving. American Association of Occupational Health Nurses, vol. 49 (8), pp. 378–389 (2001)
28. Cabral, A., Souza e Silva, M., Louzada, E., Cesar, W.: An ergonomic analysis of work in the process of professional rehabilitation in Brazil. Work **41**(1), 1841–1848 (2012). (Reading, Mass.)
29. Grayson, D., Dale, A.M., Bohr, P., Wolf, L., Evanoff, B.: Ergonomic evaluation: part of a treatment protocol for musculoskeletal injuries. Am. Assoc. Occup. Health Nurses J. **53**(10), 450–457 (2005)
30. Chetty, L.: Physiotherapy and ergonomics for a work-related musculoskeletal disorder. Int. J. Ther. Rehabil. **17**(2), 84–91 (2010)
31. Fabrizio, P.: Ergonomic intervention in the treatment of a patient with upper extremity and neck pain. Phys. Ther. **89**(4), 351–360 (2009)
32. Lincoln, A.E., Feuerstein, M., Shaw, W.S., Miller, V.: Impact of case manager training on worksite accommodations in workers' compensation claimants with upper extremity disorders. J. Occup. Environ. Med. **44**(3), 237–245 (2002)
33. Povlsen, B.: Physical rehabilitation with ergonomic intervention of currently working keyboard operators with nonspecific/Type II work-related upper limb disorder: a prospective study. Arch. Phys. Med. Rehabil. **93**(1), 78–81 (2012)
34. Sherrod, C., Casey, G., Dubro, R.E., Johnson, D.F.: The modulation of upper extremity musculoskeletal disorders for a knowledge worker with chiropractic care and applied ergonomics: a case study. J. Chriopractic Med. **12**(1), 45–54 (2013)
35. Leyshon, R.T., Shaw, L.E.: Using the ICF as a conceptual framework to guide ergonomic intervention in occupational rehabilitation. Work **31**(1), 47–61 (2008)
36. Cole, D.C., Hogg-Johnson, S., Manno, M., Ibrahim, S., Wells, R.P., Ferrier, S.E.: Worksite upper extremity research group; reducing musculoskeletal burden through ergonomic program implementation in a large newspaper. Int. Arch. Occup. Environ. Health **80**(2), 98–108 (2006)
37. Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W.S., Wilson, J.R., van der Doelen, B.: A strategy for human factors/ergonomics: developing the discipline and profession. Ergonomics **55**(4), 377–395 (2012)
38. Falzon, P., Nascimento, A., Gaudart, C., Piney, C., Dujarier, M.A., Germe, J.F.: Performance-based management and quality of work: an empirical assessment. Work **41**(1), 3855–3860 (2012)
39. Falzon, P.: Constructive Ergonomics, p. 294. CRC Press, Boca Raton (2014). Edited by Pierre Falzon

Task Analysis and Comfort Evaluation Through Simulations: Differences Between Subjective Perceptions and Simulated Data in the Case of Car-Hood Lifting

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Abstract. The preventive evaluation of perceived (dis)comfort during the early stages of the design process is still an open issue. In Car development process, all tasks that involve human operations have to be taken into account while thinking and developing new solutions. Fortunately, modern technologies like CAE (Computer Aided Engineering) and DHM (Digital Human Modeling), and some new simulation software, like AnyBody™ or Jack© by Siemens PLM, allow to investigate, through simulation, some of the aspects related to comfort perception in humans. In addition, the software named CaMAN®, developed at University of Salerno, allows the postural comfort evaluations of upper limbs. The questions to which this paper tries to give answers are: (1) Is it possible to correlate the simulated muscular activation with perceived (dis)comfort during a manual task? (2) How different are the subjective perceived (dis)comfort, rated by the Borg Scale and the (dis)comfort index calculated by software?

Keywords: (Dis)comfort perception · Muscular fatigue evaluation · Task analysis · Human factors · Car-Subsystems development · Comfort driven design

1 Introduction

The preventive evaluation of perceived (dis)comfort during a manual task in the early stages of the design process is still an open issue. In car development process, all tasks that involve human operations have to be taken into account while thinking and developing new solutions; in these new solutions, car's geometry/layout characteristics and subjective factors may heavily affect the human perception about (dis)comfort while performing these tasks. Modern technologies like CAE (Computer Aided Engineering) and DHM (Dig Human Modeling) already offer several tools for a preventive evaluation of ergonomic parameters for users, using detailed CAD (Computer Aided Design) models of car and the MBS (multi-body-system) solver for evaluating

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movements and interactions. ISO 11228 provides reference information for ergonomics and comfort evaluation by introducing parameters for evaluating postural ergonomics for the manual push/pull and lift/carry of loads, and for repetitive actions. These parameters can be fused into a "postural load index" that represents ergonomic levels for posture [1, 2]. A general instrument/method to evaluate and objectivize perceived comfort, not only based on questionnaires, market researches, or physiological and biomechanical analyses, is needed for integrating a preventive comfort analysis into the Product Development Plan (PDP). Digital Human Modelling (DHM) systems like DELMIA® or Jack© and other kinds of software like CaMAN® [3–5] can help designers to do this and to present their evaluations using a synthetic index [6, 7]. AnyBody™ is a musculoskeletal modeling system capable to perform an objective postural comfort evaluation is the study of HMI (Human Machine Interfaces); it was developed for modelling the physical behavior of joints and muscles, like the spine [8] and the mandible [9]; for the whole body segments, developers of AnyBody™ paid attention to validate the biomechanical response [10, 11]. In our study, the previously cited software were used to perform analyses and find results.

2 State of the Art

Rapid Upper Limb Assessment (RULA) [12], Rapid Entire Body Assessment (REBA) [13] and Loading of the Upper Body Assessment (LUBA) [14] are well-known methods to conduct ergonomics evaluations. Even if, in the past 20 years, many papers have dealt with "comfort", rating comfort is still an open problem due to the subjective nature of perception. Methods such as "rating of perceived exertion" [15] have been developed to "measure", for example, postural comfort under load by Local Perceived Exertion (LPE) scale. However, this method seems not sufficient for decoding the entire range of perceived comfort/discomfort. Considerable research has resulted in many papers dealing with perceived levels of comfort/discomfort, but the majority of them discusses the relationships among environmental factors, such as temperature [16], humidity and applied forces [17], or assume that a relationship exists between self-reported discomfort and musculoskeletal diseases [18]. Five main factors regarding the relationship between subjective perceptions of comfort/discomfort and products, processes, interactions, environment, and users have been discussed in [19], in which there is an interesting schematization of the mechanism of comfort/discomfort perception that comes from the Moes' model [20]. This model has been upgraded by Naddeo et al. [21], as shown in Fig. 1 (I = interaction; H = human body effects, P = perceived comfort, C/N/D = comfort/nothing/discomfort), to take into account expectations (E) [23, 33] and changes in perception due to testing devices. Steady postures have been extensively studied in the last 10 years [12, 22] and Naddeo et al. [4] defined a rating scale for upper limbs' posture evaluations. Also, prolonged and moving postures have been studied in recent years. The most studied situations concerned comfort on seats like in Bazley et al. [23], Porter et al. [24], Jackson [25], Na et al. [26], Trapanese et al. [27] and Le et al. [28]; in these papers, several relationships between (dis)comfort and time/tasks have been highlighted. In particular, Na et al. [26] discovered that comfort and discomfort are related to muscular activation. Postures under loads have been studied in order to understand the effect on the body of muscular activation under loads, force distribution and muscular/tendons/ligaments fatigue The majority of them used AnyBody™ simulations to study comfort and ergonomic postures is available: Wehner et al. [29] used AnyBody™ to determine tridimensional tibial load for implant design, comparing results with in vivo tests. In Wu et al. [30], EMG and AnyBody™ results were paired in order to optimize a computer's ergonomic keyboard design. In Cronskär [31], a method for finite element simulations of stresses in the clavicle plate and bone was used avoiding often contradictory data from experimental subjects.

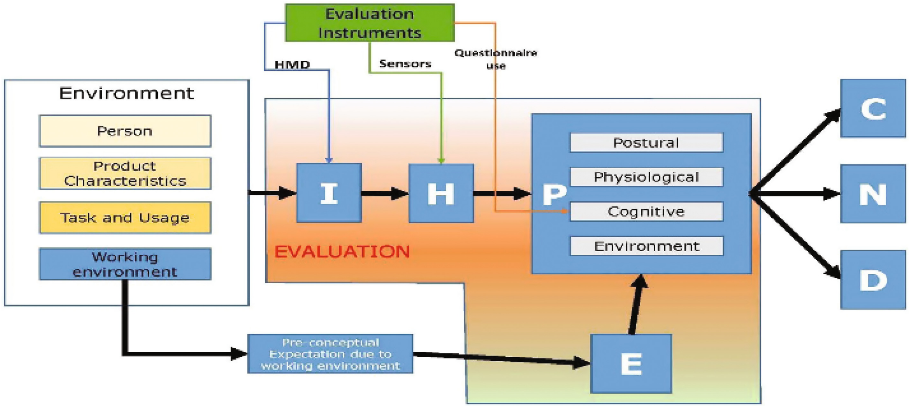

Fig. 1. Cappetti and Naddeo comfort/discomfort perception model

3 The Aim of This Research

The goal of this work is to explore and assess the correlation between two sciences: biomechanics and ergonomics. Similar studies, carried out in several working environments, have shown that greater comfort corresponds to less activation of the muscular system; in this work two specific models were constructed, the first for an ergonomic evaluation and the second for a biomechanical evaluation, to demonstrate this statement. Data that could be compared, were obtained from the models and allow to estimate and investigate the type of correlation between the two sciences. This paper shows the results obtained through the numerical/experimental analyses made by AnyBody™ and Jack© of a real human task: software were used to perform simulations of static and dynamic behavior of a subject that needs to lift a SUV (Sport Utility Vehicle) car-hood to perform controls or refills. The paper shows the differences among the results of preventive analyses of perceived effort, made with the applied load consisting of the weight of the hood, for several subjects belonging to different percentiles.

4 Tools and Methods

The basic idea was to start by acquiring the postures during a car-hood lifting by video/photographic acquisition; to use a simplified human-sized manikin capable of reproducing a wide range of postures to model the studied task (car-hood lifting); to analyze and evaluate the movements for performing the task using a commercial software (manikin) to obtain the overall postural comfort value; and finally to reproduce the under-load postures during the movement using a bio-fidelity simulation software.

The scene, consisting of car and subject, have been filmed and photographed during the task and images and videos have been analyzed and processed by the software Kinovea® in order to acquire the body joints' angles that were used for the elaborations. Jack© by SiemensPLM was chosen, as commercial manikin, for its "Force Solver" environment, which allows the realization of "digital humans" (manikins) having several controllable features: percentile, gender, race, anthropometric measures and scalability options. The man-machine interaction was modeled in Unigraphics environment at FCA labs in Pomigliano d'Arco (NA – Italy). The Force Solver is a static solver that allows to evaluate the perceived comfort, in terms of efforts, for a given posture and some given loads. The real movements have been simulated like a sequence of steady postures because no dynamic simulations are provided in it. The software outputs consist of a percentage of population that is able to perform the task; the "effort percentage" is a good index to evaluate the postural discomfort due to the task as stated in [26, 32]

AnyBody™ software has been used to realize a model that allows analyses of muscular system activation. The system comes with a full body model containing most bones, joints and muscles in the human physiognomy (over 1,000 individual muscle fascicles); it is configured to represent a typical European male (1.76 m, 75 kg), but this configuration can be easily changed. AnyBody™ uses joint motion and external force assignment to calculate the activations of the muscles responsible for a certain motion using an Inverse Dynamics process and a muscle recruitment solver to decide which muscles (each single fascicle) will be engaged. Each model in AnyBody™ consists of mechanical elements that are classified as one of four types: segments, joints, muscles and drivers. The segments represent the bones and are connected together with joints, which represent the mechanical constraints simulating the real human joints; drivers are used to manage the degrees of freedom of a joint; muscles are characterized by an initial and a final point of attachment and their selection and placement are done on the basis of the real configuration of a human. The force of gravity is always taken into account, while other loads have to be added to the model by specifying the point of application. The user can choose to have, as output, several parameters among the ones available in the software. In this work, one of the main parameters investigated is called "Envelope", which returns the maximum value of muscle activation. Each part or subassembly of the body can be defined as a "block" and analyzed in terms of all parameters. For example, the Envelope parameter for a block (e.g. the right arm) returns the values of muscle activation registered in any arm's muscle and in the entire block. These values are very interesting because they can be compared with the data coming from the comfort analysis that involves a complex part of the body (or the entire body) like the ones coming from "Force Solver" of Jack©.

5 Correlation Test

The first test has been made in order to understand if the used software can be compared each other. The comparing test consisted of a weight lifting in standing position with the arm along the body, simply using the elbow and the wrist as active joints. The weight has been simulated through a load applied in the center of the right hand, with its palm up. The static configuration has been used to analyze the static effort to maintain the weight at a height corresponding with a 90° elbow position. A normo-type human (height 1.70 mt., weight 75 kg) has been used to perform this task. As stated in the Jack© software manual, the maximum weight that can be lifted by a normal people in these conditions is about 13,20 kg. The AnyBody™ and the Jack© manikins have been compared in terms of multi-body structure and the load position has been tuned in order to preserve the right distance between the elbow joint and the point of the force application (to have the same results in terms of force's moments).

The test was performed for four different weights: 0 kg, 5 kg, 10 kg and 15 kg. The obtained results are shown in the following tables; in the right part is possible to see results coming from AnyBody™ in terms of calculated moments in the joints and of global muscular activation of the right arm; in the left part is possible to see results coming from the Force Solver of Jack© in terms of calculated moments in the joints and

Table 1. Results - first campaign of tests, Applied load = 0 kg, Subject H = 1.7 mt., W = 75 kg

Force Solver (Jack©)			AnyBody™		
Joint	Capable [%]	Moment [Nm]	Joint	Moment [Nm]	Muscular activation [%]
R Wrist Flx	100	0,1	Wrist flexion	0,22	7,6
R Wrist Dev	100	N/A	Wrist abduction	0,0063	
R Wr SuPr	100	N/A	Elbow pronation	0,047	
R Elbow	100	2,2	Elbow flexion	2,79	
R Sh AbAd	100	1,9	GlenoHumeral flexion	3,05	
R Sh Hmrl	100	N/A	GlenoHumeral ext. rotation	1,12	

Table 2. Results - first campaign of tests, Applied load = 5 kg, Subject H = 1.7 mt., W = 75 kg

Force Solver (Jack©)			AnyBody™		
Joint	Capable [%]	Moment [Nm]	Joint	Moment [Nm]	Muscular activation [%]
R Wrist Flx	98	2,5	Wrist flexion	3,55	52.8
R Wrist Dev	100	N/A	Wrist abduction	0,062	
R Wr SuPr	100	N/A	Elbow pronation	1,16	
R Elbow	100	17,1	Elbow flexion	18,75	
R Sh AbAd	100	16,0	GlenoHumeral flexion	18,8	
R Sh Hmrl	100	N/A	GlenoHumeral ext. rotation	6,9	

of percentage of saturation of capability of muscles involved in the use of each joint (Tables 1 and 2).

As can be seen, both software calculate a non-zero reaction without any load applied, due to the own weight of the forearm; moreover, the software give different values of moments in the same conditions; this difference is due to the big difference

Table 3. Results - first campaign of tests, Applied load = 10 kg, Subject H = 1.7 mt., W = 75 kg

Force Solver (Jack©)			AnyBody™		
Joint	Capable [%]	Moment [Nm]	Joint	Moment [Nm]	Muscular activation [%]
R Wrist Flx	89	4,9	Wrist flexion	6,89	98
R Wrist Dev	100	N/A	Wrist abduction	0,13	
R Wr SuPr	100	N/A	Elbow pronation	2,26	
R Elbow	98	31,9	Elbow flexion	34,7	
R Sh AbAd	98	30,1	GlenoHumeral flexion	34,67	
R Sh Hmrl	100	N/A	GlenoHumeral ext. rotation	12,75	

Table 4. Results - first campaign of tests, Applied load = 13.2 kg (bolded is a not tolerable effort), Subject H = 1.7 mt., W = 75 kg

Force Solver (Jack©)			AnyBody™		
Joint	Capable [%]	Moment [Nm]	Joint	Moment [Nm]	Muscular activation [%]
R Wrist Flx	**74**	6,4	Wrist flexion	9	127
R Wrist Dev	100	N/A	Wrist abduction	0.17	
R Wr SuPr	100	N/A	Elbow pronation	2,97	
R Elbow	92	41,4	Elbow flexion	44,9	
R Sh AbAd	94	39,1	GlenoHumeral flexion	44,76	
R Sh Hmrl	100	N/A	GlenoHumeral Ext. rotation	16,47	

Table 5. Results - first campaign of tests Applied load = 15 kg (bolded is a not tolerable effort), Subject H = 1.7 mt., W = 75 kg

Force Solver (Jack©)			AnyBody™		
Joint	Capable [%]	Moment [Nm]	Joint	Moment [Nm]	Muscular activation [%]
R Wrist Flx	**63**	7,2	Wrist flexion	10,22	143
R Wrist Dev	100	N/A	Wrist abduction	0,199	
R Wr SuPr	100	N/A	Elbow pronation	3,38	
R Elbow	85	46,7	Elbow flexion	50,71	
R Sh AbAd	89	44,2	GlenoHumeral flexion	50,47	
R Sh Hmrl	100	N/A	GlenoHumeral ext. rotation	18,57	

between the multi-body structure of the manikins and the AnyBody's one. Nevertheless, as the following tables show, the differences can be defined as "predictable", even if they have to be taken into account, because, in terms of percentage, remain about the same when the weight to lift increases (Tables 3, 4, 5 and 6).

Table 6. Percentage difference when human-limit load is applied

Subject height: 170 cm subject weight: 75 kg Applied load: 13.2 kg		
Joints angles	Δ%	ΔNm
Wrist flexion	–28,89%	2,60
Wrist abduction	N/A	N/A
Elbow pronation	N/A	N/A
Elbow flexion	–7,80%	3,50
GlenoHumeral flexion	–12,65%	5,66
GlenoHumeral ext. rotation	N/A	N/A

6 Car-Hood Lifting Test

Nine subjects, all volunteers, participated in the experiment. None had a history of musculoskeletal diseases. The main characteristics of the subjects in terms of weight, height and main anthropometric characteristics have been acquired and stored. All subjects were informed of the nature of the tests, and written consent was obtained. The Ethical Guidelines of both the University of Salerno and Italian Law were respected while performing the tests. The test case has been realized in collaboration with FCA research lab in Pomigliano d'Arco (NA) Italy. The chosen car was a FCA mini-SUV whose front car-hood has been lifted for performing the tests.

Analysis, modelling and simulation have been made through the following steps:

- In AnyBody™ and in Jack© software environment, the kinematics and geometry of the car-hood were modelled and positioned in order to perform the simulations.
- 25 physical tests have been made in order to understand the human behavior while lifting the car-hood. The photo/video acquisitions allow to study all humans' movements for lifting the car-hood. Acquired images have been used for postural analysis while video acquisition has been used for the movements' timing.
- Both in AnyBody™ and in Jack© environment, the human-hood interaction has been modelled and simulated. The arms/hands movements are complicated and involve a lot of rotation and changes of position. Due to that, the simulation has been divided in three main steps: in the first one, the subject applies a force that causes a hood's constant acceleration; in the second one, the human lifts the car-hood with a constant velocity, and in the third one, the subject uses a constant deceleration for moving up and completing the car-hood lifting, and to stop it.

Once the simulation model has been defined and tuned, nine physical tests have been performed with subjects of different percentile. Each subject was asked to answer to a question about the perceived exertion by selecting a value in the Borg scale [15].

Each test has been modelled both in AnyBody™ and in Jack© environment and was analyzed. Immediately it was evident that Jack© software is not capable to perform dynamic simulations. Therefore, we try to override this issue by creating a sequence of static positions that represents the sequence of actions in the three steps. The results, in terms of perceived efforts, were too much different from the calculated muscular/ comfort values given by AnyBody/questions. Due to that, the Jack© model was discarded and the simulations were made only by AnyBody™ software. In the following figures the results of a subject's model (1.66 m e di 67 kg) are shown. In the top-left graphs the curves of right and left arms (legs) are systematically overlapped (not visible) because of the perfect symmetry of the task. As can be seen, in the first step, the upper limbs are the most involved in terms of muscular activation. Nevertheless, an activation of trunk and lower limbs can be noted. In the second step, a higher muscular activation of upper limbs can be noted. During the third step, the muscular activation of the upper limbs goes down and the trunk and the legs increase their efforts to lift the car-hood. This behavior is due to the height of the car-hood (the chosen car is a SUV with a high Z position for the hood.) towards the height of the subject (Figs. 2 and 3).

The results of the analysis of efforts while performing the task is the following:

- The first step is critical for the upper limbs; in this step, the most part of the efforts is required to arms' muscles.
- The final part of the movement (second part of the third step) is critical for the trunk and the spine, because of the height of the car hood and, perhaps, also because of the low height of the subject.

The simulated behavior is perfectly in accordance with the answer given by the subject to the effort questionnaire (Fig. 4).

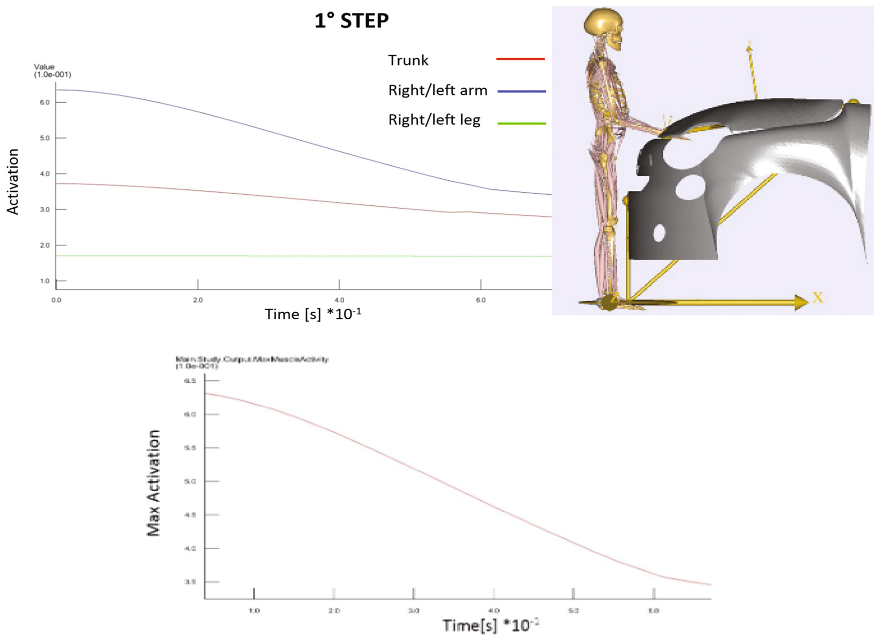

Fig. 2. Muscular activations in time (top left) and the highest muscular activation in time (bottom) in the first step of simulation (top right).

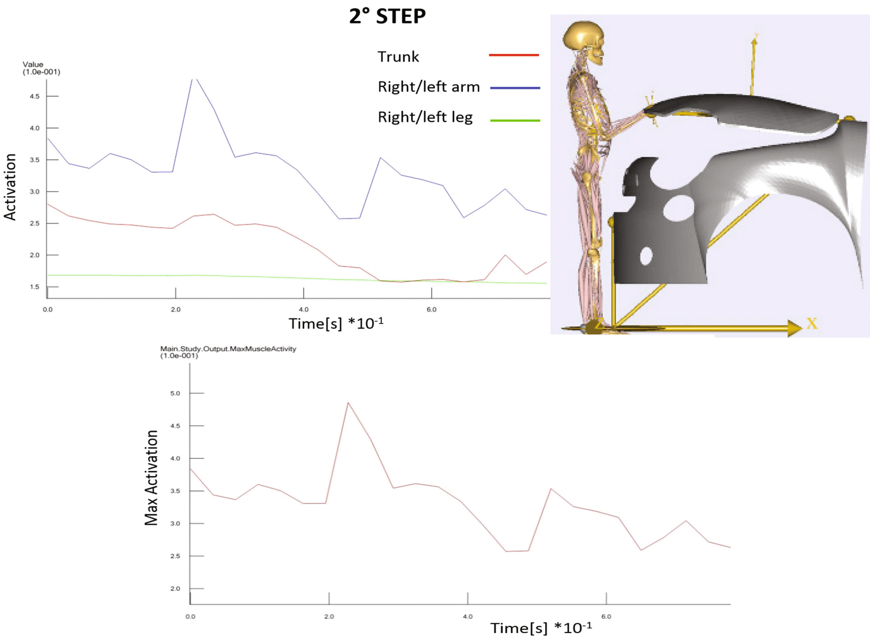

Fig. 3. Muscular activations in time (top left) and the highest muscular activation in time (bottom) in the second step of simulation (top right).

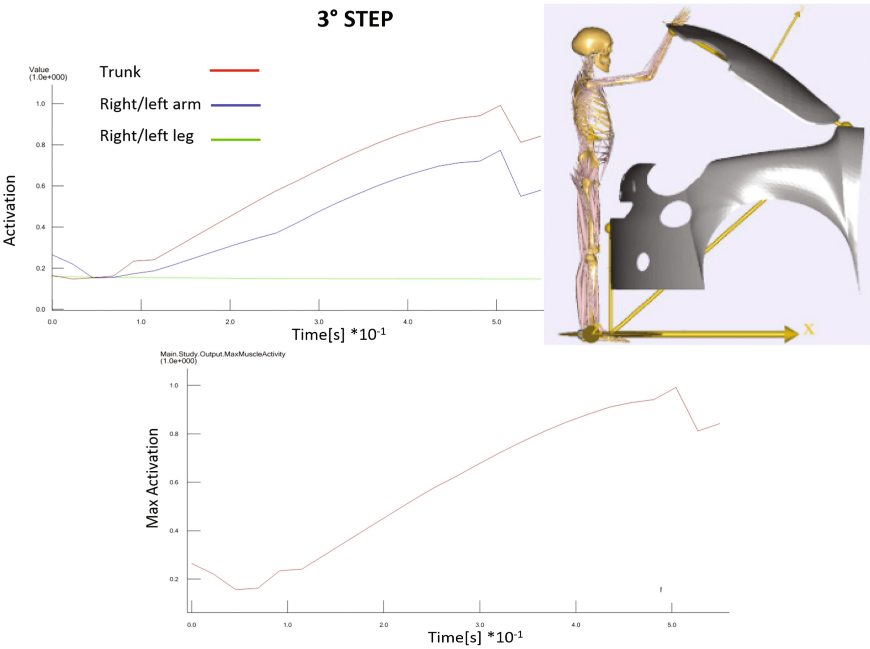

Fig. 4. Muscular activations in time (top left) and the highest muscular activation in time (bottom) in the third step of simulation.

7 Results

In the following Table 7, results coming from AnyBody™ simulations are shown. In the left side of the table, there are the anthropometric characteristics of the subjects, in the center of the values of the higher muscular activation and the average value in the whole simulation, in the right side, the perceived effort in Borg Scale.

As can be seen in those values, lower height people show the higher muscular activation in the final part of the movement, due to their low stature towards the high position of the SUV-hood; higher height people show their higher effort in the first part of the movement due to the spinal flexion they are obliged for their height.

The higher is the height of the subject the lower is the average effort during the whole movement for car-hood lifting. Each subject exerts a medium-high level of effort and that implies a medium-high level of LPE for the entire analyzed sample.

Nevertheless, even if we find high muscular activation and high values of perceived exertion, there is no statistical correlation nor in the average values and in single step's values.

Table 7. results coming from AnyBody™ simulations

Height [cm]	Weight [kg]	Max Act. I STEP	Max Act. II STEP	Max Act. III STEP	Average	Perceived effort
157	55	61,78%	63,08%	126,42%	83,76%	13
160	55	63,47%	62,33%	100%	75,27%	14
166	67	63,5%	48,6%	99,2%	70,43%	11
169	68	65,85%	46,61%	88,47%	66,98%	8
170	60	69,60%	44,30%	75,80%	63,23%	13
174	74	69,60%	38,15%	73,07%	60,27%	15
180	95	74,20%	38,70%	56,65%	56,52%	16
185	80	87,44%	44,44%	47,04%	59,64%	12
187	95	90,17%	38,70%	45,13%	58,00%	13

8 Conclusions

Through the comparison of AnyBody™ and Jack© software, is possible to assert that in the static simulation, Jack© and AnyBody™ models run very well their simulation and allow to understand the perceived level of (dis)comfort. Even the Jack© human model is simpler than the AnyBody™ one, the obtained results can be used for Comfort-driven design of human-artifact interfaces with limited movement (quasi-static analysis).

In the Dynamic analysis, Jack© software does not allow to perform simulations that can be used for assessing the (dis)comfort of an interaction. AnyBody™ software seems to be a powerful instrument to perform human-artifact interaction simulation and gives very reasonable results. Nevertheless the muscular activation cannot be used as a good indicator of perceived discomfort (in terms of perceived efforts) because, probably, other factors like spine position, human joint's posture and psycho/physiological aspects of the action affect the perception of the effort and, in consequence, of the (dis)comfort. One of the limitation of this study (that might causes the lack of statistical correlation) can be found in the low number of subjects used for the test; another probable reason for the lack of correlation is the weight and the uncomfortably layout of the used SUV-hood. In order to override those troubles, a future experiment might involve a wider sample and might be performed on a vehicle with a lighter hood in order to be more comfortable. In fact, the majority of the subjects said, in their answers, that the perceived exertions were high (up to 16/20) and 11 on 12 gave an evaluation of effort greater than 11.

The AnyBody™ software is suitable to perform very good simulations and to drive the designers to the right choice towards the anthropometric characteristics of the user.

References

1. Annarumma, M., Pappalardo, M., Naddeo, A.: Methodology development of human task simulation as PLM solution related to OCRA ergonomics analysis. IFIP Int. Fed. Inf. Process, vol. 277, pp. 19–29 (2008). doi:10.1007/978-0-387-09697-1_2
2. Naddeo, A., Memoli, S.: Postural comfort inside a car: development of an innovative model to evaluate the discomfort level. SAE Int. J. Passeng. Cars - Mech. Syst. **2**(1), 1065–1070 (2009). doi:10.4271/2009-01-1163
3. Naddeo, A., Cappetti, N., Ippolito, O.: Dashboard reachability and usability tests: a cheap and effective method for drivers' comfort rating, SAE Technical Paper n. 2014-01-0455 (2014). doi:10.4271/2014-01-0455
4. Naddeo, A., Cappetti, N., D'Oria, C.: Proposal of a new quantitative method for postural comfort evaluation. Int. J. Ind. Ergon. **48**, 25–35 (2015). doi:10.1016/j.ergon.2015.03.008
5. Naddeo, A., Cappetti, N., Califano, R., Vallone, M.: Manual assembly workstation redesign based on a new quantitative method for postural comfort evaluation. Appl. Mech. Mater. **459**, 368–379 (2013). ISBN:978-303785923-0
6. Sousa, L., Pinho, M., Arezes, P., Gòis, J.: University classrooms and students' compatibility. In: Proceedings of the 5th International Conference AHFE 2014, pp. 1055–1066 (2014)
7. Vallone, M., Naddeo, A., Cappetti, N., Califano, R.: Comfort driven redesign methods: an application to mattresses production systems, Open Mech. Eng. J. **9**, 492–507 (2015)
8. de Zee, M., Hansen, L., Wong, C., Rasmussen, J., Simonsen, E.B.: A generic detailed rigid-body lumbar spine model. J. Biomech. **40**(6), 1219–1227 (2007)
9. de Zee, M., Dalstra, M., Cattaneo, P.M., Rasmussen, J., Svensson, P., Melsen, B.: Validation of a musculo-skeletal model of the mandible and its application to mandibular distraction osteogenesis. J. Biomech. **40**(6), 1192–1201 (2007)
10. Andersen, M.S., Damsgaard, M., MacWilliams, B., Rasmussen, J.: A computationally efficient optimisation-based method for parameter identification of kinematically determinate and over-determinate biomechanical systems. Comput. Methods Biomech. Biomed. Eng. **13**(2), 171–183 (2010)
11. Lund, M.E., de Zee, M., Andersen, M.S., Rasmussen, J.: On validation of multibody musculoskeletal models. Proc. Inst. Mech. Eng. [H] **226**(2), 82–94 (2012)
12. McAtamney, L., Corlett, E.N.: RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)

13. Hignett, S., McAtamney, L.: Rapid Entire Body Assessment (REBA). Applied Ergonomics **31**(2), 201–205 (2000)
14. Kee, D., Karwowski, W.: LUBA: an assessment technique for postural loading on the upper body based on joint motion discomfort and maximum holding time. Appl. Ergon. **32**, 357–366 (2001)
15. Borg, G.: Psychophysical Bases of Perceived Exertion. Med. Sci. Sports Exerc. **14**, 377–381 (1982)
16. Califano, R., Naddeo, A., Vink, P.: The effect of human-mattress interface's temperature on perceived thermal comfort. Appl. Ergon. **58**, 334–341 (2017)
17. Galinsky, T.L., Swanson, N.G., Sauter, S.L., Hurrell, J.J., Schleifer, L.M.: A field study of supplementary rest breaks for data entry operators. Ergonomics **43**, 622–638 (2000)
18. Naddeo, A., Apicella, M., Galluzzi, D.: Comfort-driven design of car interiors: a method to trace iso-comfort surfaces for positioning the dashboard commands. SAE Technical Papers, paper n. 2015-01-1394 (2015). doi:10.4271/2015-01-1394
19. Vink, P., Hallbeck, S.: Editorial: Comfort and discomfort studies demonstrate the need for a new model. Appl. Ergon. **43**, 271–276 (2012)
20. Moes, N.C.C.M.: Analysis of sitting discomfort, a review. In: Bust, P.D., McCabe, P.T. (eds.) Contemporary Ergonomics 2005, pp. 200–204. Taylor & Francis, London (2005)
21. Naddeo, A., Cappetti, N., Vallone, M., Califano, R.: New trend line of research about comfort evaluation: proposal of a framework for weighing and evaluating contributes coming from cognitive, postural and physiologic comfort perceptions. In: Vink, P. (eds.) Advances in Social and Organizational Factors, Advances in Human Factors and Ergonomics" Conference 2014 (2014). ISBN: 978-1-4951-2102-9
22. Apostolico, A., Cappetti, N., D'Oria, C., Naddeo, A., Sestri, M.: Postural comfort evaluation: experimental identification of range of rest posture for human articular joints. Int. J. Interact. Des. Manuf., 1–14, April 2013
23. Bazley, C., Vink, P., De Jong, A., Hedge, A.: The influence of expectations and pre-experiences on comfort at work. In: Conference Proceedings 4th International Conference on Applied Human Factors and Ergonomics (AHFE), USA Publishing, San Francisco (2012)
24. Porter, J.M., Gyi, D.E., Tait, H.A.: Interface pressure data and the prediction of driver discomfort in road trials. Appl. Ergon. **34**(3), 207–214 (2003)
25. Jackson, C., Emck, A.J., Hunston, M.J., Jarvis, P.C.: Pressure measurements and comfort of foam safety cushions for confined seating. Aviat. Space Environ. Med. **80**(6), 6 (2009)
26. Na, S., Lim, S., Choi, H.-S., Chung, M.K.: Evaluation of driver's discomfort and postural change using dynamic body pressure distribution. Int. J. Ind. Ergon. **35**(12), 1085–1096 (2005)
27. Trapanese, S., Naddeo, A., Cappetti, N.: A preventive evaluation of perceived postural comfort in car-cockpit design: differences between the postural approach and the accurate muscular simulation under different load conditions in the case of steering-wheel usage. SAE Technical Papers n. 2016-01-1434 (2016). doi:10.4271/2016-01-1434
28. Le, P., Rose, J., Knapik, G., Marras, W.S.: Objective classification of vehicle seat discomfort. Ergonomics **57**(4), 536–544 (2014)
29. Wehner, T., Claes, L., Simon, U.: Internal loads in the human tibia during gait. Clin. Biomech. **24**(3), 299–302 (2009)
30. Wu, J.Z., An, K.N., Cutlip, R.G., Krajnak, K., Welcome, D., Dong, R.G.: Analysis of musculoskeletal loading in an index finger during tapping. J. Biomech. **41**(3), 668–676 (2008)

31. Cronskär, M.: Strength analysis of clavicle fracture fixation devices and fixation techniques using finite element analysis with musculoskeletal force input. Med. Biol. Eng. Compu. **53**(8), 759–769 (2015)
32. Telfer, S., Spence, W.D., Solomonidis, S.E.: The potential for actigraphy to be used as an indicator of sitting discomfort. Hum. Factors **51**(5), 694–704 (2009)
33. Naddeo, A., Cappetti, N., Califano, R., Vallone, M.: The role of expectation in comfort perception: the mattresses' evaluation experience. Procedia Manuf. **3**, 4784–4791 (2015)

Human Factors in Designing Workspace: Customizing Kitchen Counter Design

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Abstract. Human factors focus on human beings and their interaction with products, equipment, facilities, procedures, and environments used in work and everyday living. Emphasis is on human beings rather than on technical considerations. Designing a workspace is based on the principle that there are correlations between workspace and body dimensions that cause body posture to be adapted. The current research aims at designing Kitchen workspace, Kitchen is the most important room in any household, where maximum work is carried out. The paper addresses the problems faced while working in kitchen. It reflects some suggestions to avoid fatigue and musculoskeletal disorder. This will result in efficient, fast and pleasurable cooking with less efforts.

Keywords: Human factors · Ergonomics · Workspace design · Kitchen · Anthropometry · Posture · Workspace

1 Introduction

Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of the system, and the profession that applies theory, principles, data and methods to design, to optimize human well-being and overall system performance.

Ergonomics is a term often used in the area of work conditions improvement, whereas the term human factors is defined 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 methods to design, to optimize human well-being and overall system performance" [1]. The slight difference between ergonomics and human factors is that the latter pays more attention to the psychological effects of work conditions on the individual. Human factors "is concerned with the application of what we know about people, their abilities, characteristics, and limitations to the design of equipment they use, environments in which they function, and jobs they perform." (Human Factors and Ergonomics Association) [1].

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1.1 Ergonomics and Body Posture

The relations between ergonomic traits and body posture traits have been studied in humans performing a task with predominance of static load in sitting and standing position. Even a workstation that is perfectly adjusted to body dimensions will not eliminate inconvenient working postures, because many of them have behavioral causes. Therefore, it is necessary to advise working people to maintain the perfect body posture; also, the elements on which they work should be designed such as to help them maintain their posture.

The implementation of ergonomics in system design should make the system work better by eliminating aspects of system functioning that are undesirable, uncontrolled or unaccounted for, such as

- **Inefficiency** – when worker effort produces sub-optimal output
- **Fatigue** – Improper posture induces stress at different parts of the body which results in exhaustion
- **Accidents, injuries and errors** – Poor interface design results in excessive mental and physical stress. The chances of accidents and injuries increase due to mental stress
- **User difficulties** – due to inappropriate combinations of subtasks making the dialogue/interaction becomes cumbersome and unnatural
- **Low morale and apathy.**

Systems can be improved by

- Designing the user-interface to make it more compatible with the task and the user. This makes it easier to use and more resistant to errors that people are known to make
- Changing the work environment to make it safer and more appropriate for the task
- Changing the task to make it more compatible with user characteristics
- Changing the way work is organised to accommodate people's psychological, and social needs [2].

The human factors contribution must be multiple, combining cognitive, physical and social theories, methods and knowledge

1.2 Body Posture and Workspace

Designing a workspace is based on the principle that there are correlations between workspace and body dimensions that cause body posture to be adapted. In extreme cases, the results of these correlations may be twofold:

a. Constraining of posture with consequences such as musculoskeletal complaints, when the operator adapts himself to workspace.
b. Lack of these complaints in case the workspace is adjusted to the operator.

There are strong associations between body dimensions and the adapted posture, because only high correlations will decide on the proper adjustment of the workspace to the operator.

Ergonomics aims to ensure that human needs for safe and efficient working are met in the design of work system. Through its emphasis on human element, ergonomics aims to design out deficiencies in existing system and design in reliability and good performance into new system so that system design does not degrade human performance or potential. The purpose of ergonomics is to enable a work system to function better by improving the interactions between human beings and the other components. Human behavior at the work takes place in the context of a system and is shaped by the way the system is designed.

If a physical task is to be carried out in a safe and comfortable manner, various physical requirements must be met. First, the body needs to be stable. Stability depends on the relationship between body parts and the base of support provided by the feet, the seat and any other surfaces in the workspace which can be used to support the body weight. The design of workspace can determine the range of stable postures which can be adopted and can be evaluated from this point of view. If a task requires a posture to be held for any length of time, posture analysis is necessary. Thus, it is essential to observe worker's postural behavior and postural strategies can be used both to minimize fatigue and to enable the worker to work more efficiently.

The height of the working surfaces, is important in relation to the operative's posture. On many industrial as well as domestic tasks, static fatigue is the main problem; fatigue, that is, arising not from active muscular effort but from the necessity to maintain a specific posture of the body throughout the working span - and all too often, a somewhat unnatural and uncomfortable posture [3] (Fig. 1).

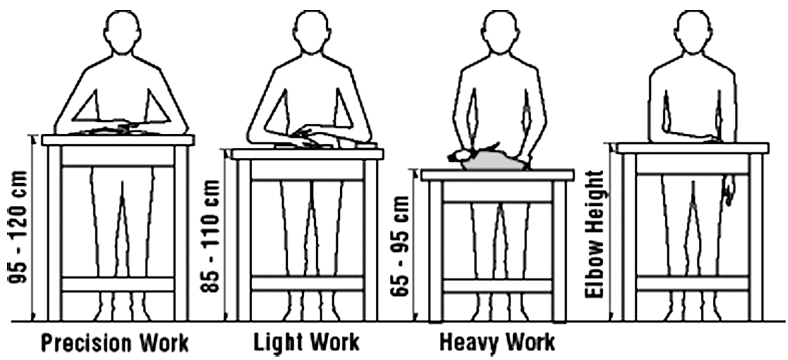


Fig. 1. Example of different heights of work platforms, according to different types of work.

2 Case Study

2.1 Kitchen as a Workspace

Kitchen is the most used room in any house and maximum activities are carried out in it. And an efficient kitchen is typically a key point in leading a comfortable life. The kitchen — unlike most other rooms in the home — is a workspace. The job of preparing and serving meals gets done there. Making that environment fit you is a most critical factor for your satisfaction within your kitchen. Ergonomics aims at making this work more efficient, faster, more pleasant, and less fatiguing by improving the interface between the human body and the things we need to interact with to get the work done. Ergonomic principles to be applied in the kitchen to make the work there more productive and efficient, no matter the size and shape of kitchen, are discussed in this paper.

Ergonomics is an applied science that deals with making systems and equipment conform to human capacity. When applied to kitchen remodeling or any other home improvement for that matter, it involves designing the layout and specific work areas to complement with the physical features of the people using the area and how they use it. This can refer to height, or other factors in the household. The harmony achieved between the design and personal needs of the family makes tasks done in the most comfortable and efficient manner.

2.2 Problem Definition

In Indian scenario, women spend at least 3 to 4 h per day in kitchen. The work involves cutting the vegetables, rolling Indian bread, cooking etc. The work is extensive due to the special type of preparation required. Also, there are at least 5–6 items to be prepared per meal. A sample of 20 typical kitchen users from different households and different kitchen environment were studied. (Study being limited to Indian urban women) Their activities, motions, postures, use of hands, forces exerted for those actions were recorded.

The most important element of the kitchen is the kitchen counter. It is observed that, while starting the work in kitchen, one starts the marathon cooking by clearing off the counter and quickly starting to chop.

Total tasks can be divided into 3 basic categories:

a. Tasks performed at the counter level (Slicing, Cutting, Mixing, Indian Bread Making etc.)
b. Tasks performed above the counter level (Cooking, Stirring, Using the Mixer etc.)
c. Tasks performed below the counter level (Using Sink, Washing and Cleaning etc.).

These actions along with their related parameters are summarized in Table 1.

The most common height for a kitchen counter top is 3-feet (36-inches). It is not the best for a specific task, but it is the best overall compromise for the majority of tasks done in the kitchen. People who are shorter or taller than the 50th percentile, or those with special needs, may want to modify that height to better suit their needs.

To determine an optimal height for kitchen working surfaces, one must consider this anthropometric diversity of the users as well as the diversity of tasks to be performed. One should expect differences, even among tasks performed upon the surface itself, associated with varying requirements of downward force [4].

No attention is paid towards the fact that a counter too high or too low for one's height. This forces the subject to hunch over, straining the muscles in neck, shoulders, and lower back. If elbow is too high above the work surface, one tends to lean forward

Table 1. Tasks performed on the kitchen counter with related parameters

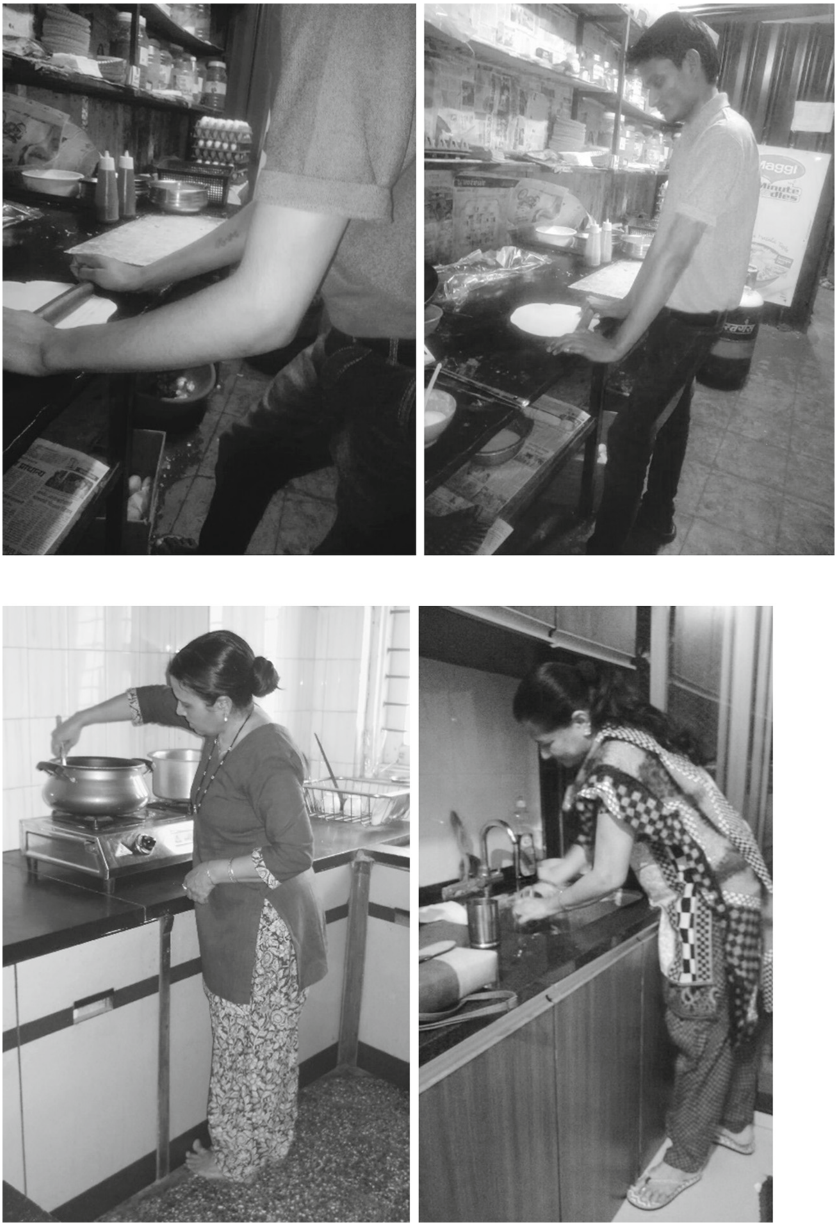
Sr. No.	Task to be performed	Use of muscular force	Posture	Anthropometric parameter
1	Cutting, slicing, chopping etc.	Little force required	Straight torso with fingers and hand moving. (Knuckle, wrist and elbow pivot)	Elbow height, Eye level
2	Putting elements into utensil for cooking	No force required	Torso bent forward with upper arm, hand and fingers moving (knuckle, elbow, shoulder, trunk pivot)	Shoulder height, Waist height
3	Stirring	Force required	Torso bent forward with hand, forearm and upper arm moving (wrist, elbow, shoulder, trunk pivot)	Shoulder height, Eye level, Waist height
4	Movement of utensils	Force required	Movement of torso, upper arm, forearm, hand, fingers (knuckle, wrist, elbow, shoulder, trunk pivot)	Waist height, Elbow height, Shoulder height
5	Washing	Little force required	Straight torso with fingers, hand, forearm and upper arm moving (knuckle, wrist, elbow, shoulder pivot)	Waist height, Shoulder height
6	Using mixer, food processor etc.	Little or no force required	Straight torso with fingers, hand and arm moving (knuckle, wrist, elbow, shoulder pivot)	Shoulder height, Eye level

to put elbows back in an optimal relation to the countertop. If elbow is too close to the work surface, one tends to either step or lean back to being the elbows back into the correct position. In either case, the back suffers (Fig. 2).

2.3 Effects of a Faulty Kitchen Counter

a. Working with hands too high and/or too far away – compensatory load on the curvature of the back
b. Work surface too low – trunk flexion and back muscle strain
c. Constrained foot position due to lack of clearance – standing too far away
d. Working at the corner of counter – constrained foot position, toes turned out very much
e. Standing in uncomfortable posture for a long time or twisted spine
f. Tall person has to lean a lot while working at sink, whereas short person has to stretch shoulders and elbows to work above the counter.

Thus, lower back pain, neck pain, feet joint pain, shoulder pain are the most common complaints among the regular users in the kitchen [5, 6]. Prevention of these



(a)

(b)

Fig. 2. (a) Different postures adapted while making the Indian Bread; (b) Postures forced because of inconvenient counter heights, also toes folded/turned out because of lack of space at the bottom.

is possible by implying ergonomic kitchen practices i.e. redesigning or customizing the kitchen counter as per the user's needs.

2.4 Proposed Suggestions for Designing and/or Modifying the Kitchen Counter

Frank Gilbreth and Lillian Gilbreth, conducted some fascinating experiments in the kitchen, eventually developing a plan for kitchen spaces. These kitchen spaces minimized unnecessary motions and movements, but ultimately—and perhaps most importantly—allowed and encouraged customization and flexibility. They were intended to enable the user to organize the home according to one's own work habits. There was no ideal solution; the height of a kitchen counter must be adjusted to the height of the person, and the most useful layout would vary from one household to other [7].

Ward and Kirk (1970, UK) studied these matters and BS 3705 (published in 1972) reads thus: 'Subject to the need for field research and solving technical problems, it is thought that a 50-mm incremental range of heights of working surfaces may be adopted in the future, the ranges being 900 to 1050 mm for sinks and 850 to 1050 mm for worktops. 'Adjustments can be different plinth heights and other means' [4]. These results refer to the population of UK. No such study is available in literature for the Indian population. The cooking habits, preparation procedures and anthropometry of Indian population differs to a great extent from American and European population.

It is essential that the one working in the kitchen should be comfortable for the performing tasks so as to avoid any errors, injuries or accidents. Following points can be considered while designing a kitchen counter:

1. Customizing counter heights, rather than forcing the body to adapt to standardized sizes.
2. Consider installing two or more counters at varying heights i.e. make steps on the counter (Refer Fig. 3). For example,
   a. Utensils put on the burner should be a little lower so as to have better visibility inside the pot.
   b. Hand mixing should also be at a lower level for better leverage and proper ergonomic alignment.
   c. For washing dishes, the working surface is not the countertop, but the bottom of the sink. So, sink depth is an issue.

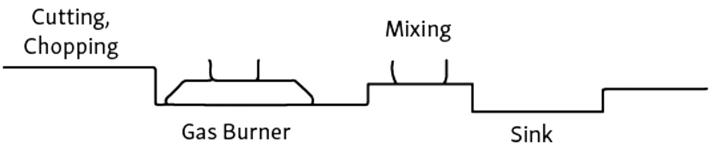


Fig. 3. Different heights for different tasks.

d. Baking also requires a lower working surface. When rolling out dough, you want to lean forward a little to put your back into the process so your arms and shoulders do not have to do all the work.
e. Base counter height is found when, with palms on the counter-top, arms rest at a 45-degree angle to the countertop. For chopping, slicing and most food assembly, this is the optimum height.

3. There should be enough space provided below the kitchen counter to accommodate the feet of the operator, so that one can stand close to the platform and need not lean forward (Refer Fig. 4).
4. With the existing kitchen counter,
   a. First check the height of the counter before you slice and dice. Put your arms at your sides and bend your elbows to 90 degrees.
   b. The surface should be no more than a few inches below your hands. If it's too low, stack cutting boards; if it's too high, stand on a sturdy platform. Height of the platform should be equal to that of gas burner.
   c. To lessen back strain, stand with your feet shoulder width apart, shoulders back and knees soft [8].

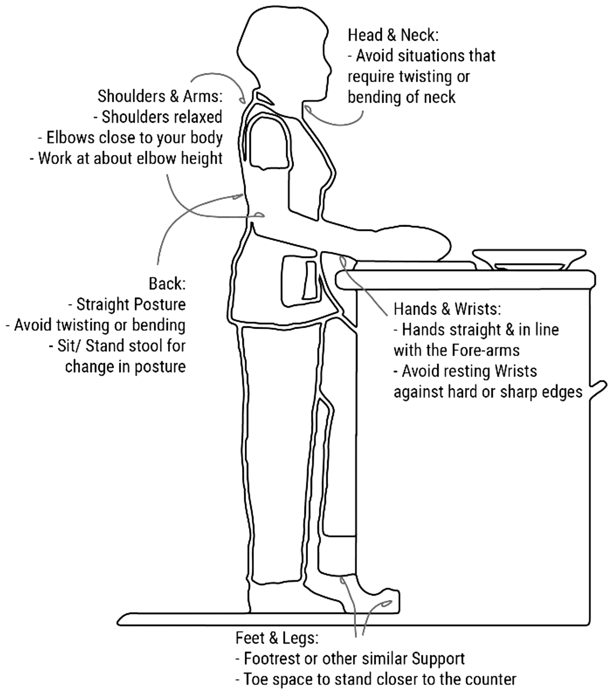


Fig. 4. An indicative sketch of ideal posture for working at Kitchen Counter.

3 Conclusion

The reduction of postural stresses is fundamental to workspace design in ergonomics. A multifaceted approach is needed to arrive at appropriate workspace designs for different workers. Of the specialized spaces of the home, the kitchen is the one that can most obviously be treated as a functional workspace and hence, the human factors play key role in designing this workspace.

To determine an optimal height for kitchen counter, one must consider both the anthropometric diversity of the users and the diversity of tasks to be performed. Because the kitchen counter is used by everyone in various age groups with variable physique, it is needed to be designed according to everyone's needs and convenience. If the user working at the counter gives a thought to the working parameters before starting the work hastily, a lot of pain in the future can be saved. Design of kitchen platform cannot be generalized but it is to be customized by means of anthropometric parameters and ergonomic considerations.

References

1. Boatca, M., Elena, C.B.: A proposed approach for an efficient ergonomics intervention in organizations. Procedia Econ. Finance **23**, 54–62 (2014)
2. Bridger, R.: Introduction to ergonomics. Procedia Econ. Finance Eng. **8**, 702–711 (2003)
3. Murrell, K.H.F.: Ergonomics: fitting the job to the worker. Br. Product. Counc. **109**(5056), 265–278 (1960)
4. Alston, R.: Bodyspace. Int. J. Nurs. Stud. **24**(4), 347–348 (1987)
5. Driessen, M.T., Proper, K.I., van Tulder, M.W., Anema, J.R., Bongers, P.M., van der Beek, A.J.: The effectiveness of physical and organizational ergonomic interventions on low back pain and neck pain: a systematic review. Occup. Environ. Med. **67**(4), 277–285 (2010)
6. Singleton, W.T.: Introduction to Ergonomics. World Health Organization, Geneva (1972)
7. Bell, G., Kaye, J.: Designing technology for domestic spaces: a kitchen manifesto. Gastronomica **2**(2), 46–62 (2002)
8. Kanawaty, G.: Introduction to Work Study, p. 542. International Labor Office, Geneva (1992)

Ergonomic Assessment and Workplace Design in Dairy Processing Industry

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Abstract. Ergonomics plays an important role in occupational safety, productivity and occupational diseases. For this reason, the creation of the auxiliary equipment or the machine and the work place designs to improve human life quality and working conditions is necessary at every area where manufacturing is made. Musculoskeletal System Diseases (MSDs) constitute 50% of new cases in occupational diseases. Unproper postures and ergonomic inadequacies in repetitive work activities in the formation of these diseases which may be painful during work or at rest are the main factors. Ergonomic improvements made are not only protect from occupational diseases, but also provide job satisfaction. This study has been carried out in a dairy-processing machine manufacturer where labor-intensive project-type manufacturing is conducted according to the customer orders. Human continues to be the most important element of manufacturing in this industry. So, ergonomic problems were determined by observing the all manufacturing process and suggestions were made by RULA analysis to improve existing problems by considering anthropometric data.

Keywords: Dairy process industry · Ergonomic analysis · RULA method · Working performance · Workplace design

1 Introduction

The term “ergonomics” has been is derived from the greek words ergos (work) and nomos (law) [1, 2]. Although the expression Ergonomy is pervaded in the European countries, it is called human engineering or human factors in the USA. However in Turkey it has been translated as work science by the Turkish language association [3]. Work stations and assembly cells in most manufacturing enterprises are like the heart in a humans body. The more ergonomic work stations and assembly cells are, the more efficient they get. The fact that more ergonomic work stations and assembly cells makes more efficient employees. Ergonomics is a science that is struggling to understand the interactions between people and other elements of the system. The theoretical principle of ergonomics is to use data and methods to improve human well-being and overall performance of the system. Ergonomics, as an interdisciplinary field, has three main specialties: physical ergonomics, cognitive ergonomics and organizational ergonomics [4]. Briefly, the purpose of ergonomics is that tools, technical systems and the works are designed to increase health, safety, comfort, and performance of human [5]. The working area must be developed for working in sitting or standing position [6],

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e.g. using height adjustable tables [7]. In the most general sense, working posture is the shaping of body, head, trunk, arm and leg members according to workstation design, work requirement and anthropometric data [1, 8]. Work places are shaped under the influence of human characteristics, job requirements and job design features. According to Sutton [9], systems must be designed to eliminate human failure. If the ergonomic conditions of the individuals in the work area are best met, both production efficiency and health are maintained [10, 11]. As a basic principle, the work and the work area must be arranged accordingly, so that the maximum efficiency and satisfaction of the employee is ensured [12, 13].

Ergonomic application of manual activities that directly affect physical and mental health is very important [14]. Musculoskeletal system diseases are present in 90% of handicapped and elderly workers [15]. Also, the treatment of musculoskeletal system diseases (MSD) costs tens of billions of dollars [16]. Occupational musculoskeletal disorders are indicated as one of the main causes of inefficiency, incontinence, fatigue, disability and absenteeism among workers [17, 18]. Studies on ergonomics show that the development of the best protection method from musculoskeletal system diseases (MSD) is really important and its benefit to workers and employers [19]. Ergonomic development in many sectors can be achieved through a participatory approach and training toolkit [20]. As a result, people cannot be redesigned so that the existing workspace or machines must be designed such that people can work on or use them. Improvements made will make the jobs easier and the hardest job to be done. The workspace designs should be done to ensure working comfortably rather than limiting the worker [21]. As shown in the study of Kane et al. occupational injuries and ergonomic workplace design in the formation of MSD diseases are very important factors [22]. This study has been carried out in a enterprise that has order-based labor intensive manufacturing, and provides a wide variety of machines for the milk processing industry.

In this research, a dairy- processing machine manufacturer is examined. This enterprise has project type manufacturing system where product characteristics and measurements can vary constantly according to customer demand. So, each new order is different from previous one. Also, because of the specific or custom products, single product is manufactured at a time. This production system requires different set of skills and intensive labor. In this sector where people are the most important items/elements for manufacturing, so that the working conditions were assessed from an ergonomic point of view and necessary measures were presented. There are 20 assembly shops and every product is manufactured in different assembly shop

2 Ergonomic Workplace Design

The main objective of workplace design is to provide the most comfortable environment by eliminating distraction and factors that create a physical barrier to the person. Sutalaksana et al. have analyzed the ergonomic workplace design in the roof tile industry [23]. It is imperative to consider anthropometric information for the design of machinery, vehicles and work environments [1]. The purpose of ergonomic work station that consistent with anthropometric data is to remove or minimize if the conditions don't allow removal the physical and mental strain that the person working has and harmful posture. Taking account of ergonomic rules as well as anthropometric information is a prerequisite for humane and economic use [24]. But the challenge of designing an ergonomic workplace is that the physical dimensions of people vary and are not all the same size. The importance of using anthropometric variables while designing the workplace and producing products cannot be ignored. Studies conducted on this subject show that each individual and society have unique anthropometric measurements of their own. Therefore a research was conducted to determine anthropometric measures which will be used in ergonomic design and manufacturing [25, 26]. According to the anthropometric data of 2006 men in Turkey have an average height of 168.8 cm, whole arm length of 74.85 cm, lower leg length of 48.38 cm and higher leg length of 47.50 cm. Three different measurement methods are used to determine the length dimensions of the human body. These are; the length dimensions when the person is standing still and sitting down (static anthropometry), when a section of the body is moving according to a fixed point of the body (dynamic anthropometry) and when actions need to be done besides staying in a fixed state (functional anthropometry) [4, 27].

RULA is one of the subjective observation methods that developed to reveal work related upper limb disorders taking into consideration the strength, repetitive movements, and working postures required for the task. According to this method, predetermined classifications and numerical values of the upper limb, neck, back and leg stances are used to determine the risk score of the observed posture. RULA can be useful [28] for the risk degrees of workers being exposed to work-related diseases, muscular effort, spent power and time worked without interruption.

3 Working Place

The company, is an establishment producing machines and equipment for the dairy and food industry sector since 1980. In a competitive environment, businesses need to effectively manage production inputs such as raw materials, energy, labor, capital. It is obvious that the workforce has an important place among these inputs. Work arrangements made by the employees directly affect the productivity of the production. Employee-friendly workstation design within these regulations will change performance positively [24, 28]. Workers have been observed producing a dry boiling machine in the establishment producing area in Fig. 1.

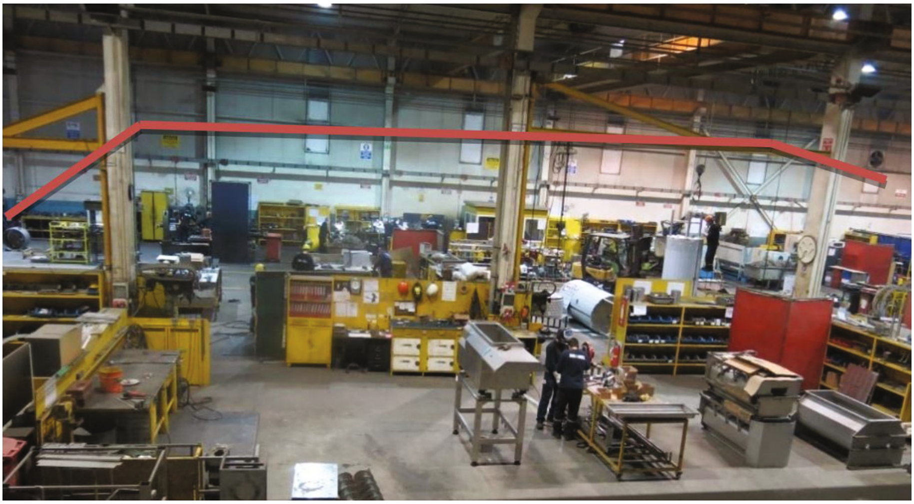

Fig. 1. Observed workplace

The body measurements of the 3 workers observed working in the part/department where dry boiling machines are produced and assembled as follows (Table 1).

Table 1. Body measurements of the workers

Height (cm)	Arm length (cm)	Leg Length
170	60	95
177	60	95
179	67	108

4 Ergonomic Analysis of the Work Place

If we start by the height of the working place we can generally say the working places are relevant for the body measurement of the workers. The reason for this is the workers generally having close body measurement to each other. There is enough room for the worker to put his legs while he is sitting down, he can even easily stand up. However there isn't enough flexibility in seating and backrest systems due to the usage of an office chair model while assembling the big pieces of the dry boiling machine on the ground (Fig. 2).

The Score of 7 obtained as a result of the evaluation of the work postures and the exposure to ergonomic risk factors in Fig. 2, by the RULA. This score indicates high risk and calls for research, urgent intervention, and the need for change. In this case, the work done should be revised immediately and necessary method changes and corrections should be made. The workers remain standing during work if the work is needed as shown in Fig. 3. Since the anthropometric dimensions change from worker to worker, some of the workers have to spend more effort for sitting or standing work.

Fig. 2. The current chair being used

Not being provided the necessary support while the workers are working, decreases will occur on efficiency after a period o time. Ease of operation can be provided to the worker in this situation by sit-stand chairs that have back and leg support which also have a proper height from the ground. The work postures and the ergonomic risk assessment in Fig. 3 are evaluated by RULA so that the final score of 3 is obtained. This score indicate unproper posture, the need for further investigation, and changes that may be required

Worker uses platform because of the different machine dimensions that arise order variability while working on it as shown in Fig. 4. Unless the platform is adjustable, it causes non-ergonomic postures, especially if there are physical and repetitive work for long time periods. RULA was used for evaluating of working position in Fig. 4, and the score of 5 was obtained as result. This indicates medium risk, unproper posture and body usage, so research and change Until the product is finally finished all the sub processes constantly need manually are neededsoon. operation while doing welding, grinding and the mounting. This is why it is very important that the workplace design that will be worked on is proper for a manual work. Generally, there is not a situation that the workers arms and legs have to move constantly but the whole process (especially welding treatment) causes the postures that are ergonomically inappropriate. Since this work doesn't have a standard time, arm and leg muscles get harmed. Moreover, resultant static working will lower the blood flow and cause fatigue as shown in Fig. 5.

In Fig. 5, the work was evaluated with the RULA and the final score of 7 was obtained. This implies false posture and body usage, so the work done must be revised and required changes must be made immediately. The welding machine which is an electrical device is used in the workplace. Heat, flares and chemical gases that are not suppose to be inhaled are exposed during the welding process. The workers doing this job are not using gas masks and however just one of the two workers is protected by

Fig. 3. Work height of the workplace

Fig. 4. Working on machine with the platform

welding mask from the heat and flares that could cause severe damage to the other worker as shown in Fig. 6. Since the welding is done in an exposed area of the workplace other workers are also effected by this situation. Adequate measures and protection has not been provided in the welding operation. All the workers who weld should take safety precautions and to decrease the harm and distraction made to other workers, the welding should be done in a different chamber or portable welding divider should use. There is a pool used for welding test, in the work place, and also it is called. Some parts of the dry boiling machine are welded inside a water pool (test pool) due to certain reasons as shown in Fig. 7. The water pool is used for welding and this pool is moveable. They can be placed randomly to empty spaces in the workplace when

Fig. 5. Postures and movements when welding is done.

Fig. 6. Welding Process

Fig. 7. Welding at the test pool

welding is needed. In appropriate work methods shown in Fig. 7 occur because of the unproper pool placement and insufficient pool height (60 cm).

The lack of a certain and sufficient working area for the test pool affects employee productivity and health, so it results in unproper posture, limited movement, and injuries. The Rula evaluation result of this working method yields the score of 7.

5 Suggestions

There are moveable machines and tools (manual welding machines, electric tools and test pools) used according to need because of the project type manufacturing system as shown in Fig. 1. Specifying and marking of the moveable machines and tools locations to be placed when the operation is to be carried out will provide organized work and sufficient work area. The chair that is being used in the workplace showed in Fig. 2 and also the working postures and methods shown in Figs. 3, and 5 are not ergonomic. In these workplaces, a chair that provides support for both the back and legs and gives an opportunity to rest should be preferred. Also recommended chair can be adjusted according to the worker as shown in Fig. 8. The RULA score was improved from 7 to 3 with this recommendation as shown in Fig. 10. This score result shows that using an ergonomics chair resulted in an efficiency increase.

Fig. 8. Recommended chair

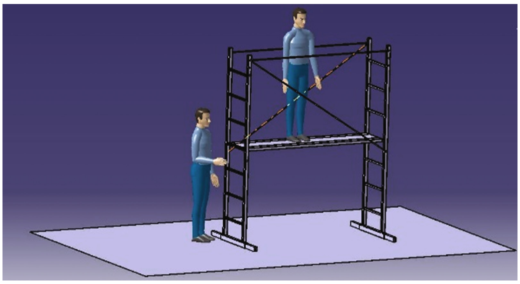

Fig. 9. Recommended platform

A platform that have a mechanism for adjusting the height according to work should be used when working on the dry boiling machine as showed in Fig. 4. Other than this platform should be surrounded by railing, so the worker using it does not encounter any work accidents. An ergonomic working environment has been provided with the recommended platform (as shown in Fig. 9.), which can be adjusted according to the anthropometric measurements of the worers. Thus, the RULA score was improved from 7 to 3 with the recommended platform as shown in Fig. 12. When the worker works on the dry boiling machine as shown in Fig. 4, the platform being used should have a adjustable height mechanism according to work to be done.

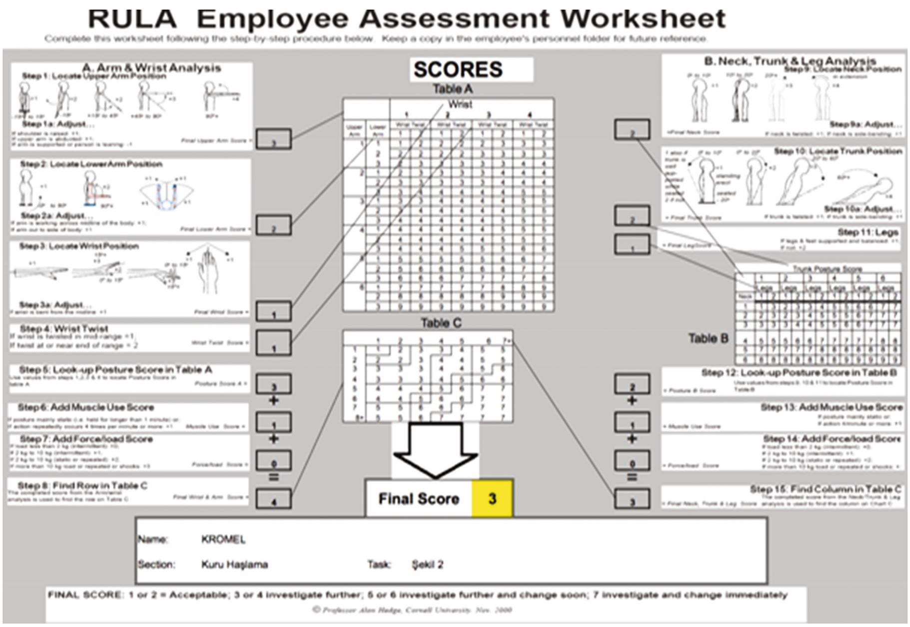

Fig. 10. Improved RULA score result of Figs. 2, 3 and 5 by recommended chair.

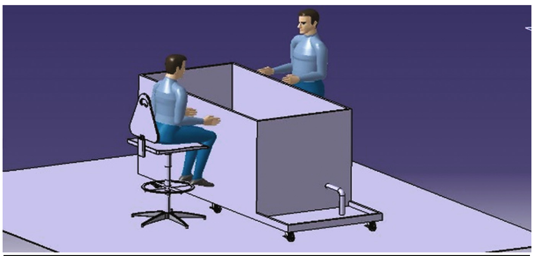

Fig. 11. Recommended pool height and working method

Movable water pool is used for testing of welding operation, so the place of the pool shown in Fig. 7 should be determined and marked. When a job is going to be done the workplace where the water pool will be placed should be sufficient, open and prepared in advance.

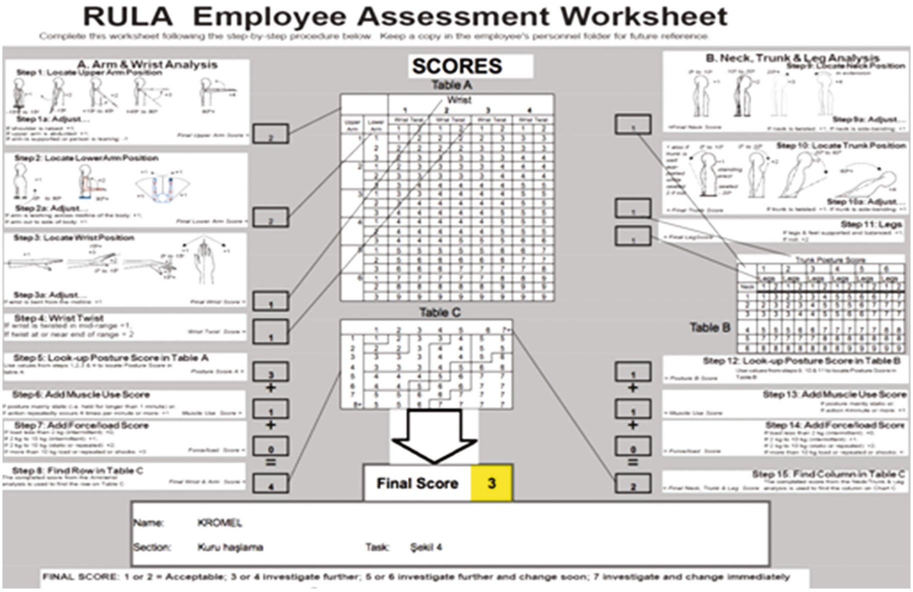

Fig. 12. The improved Rula score result of Fig. 4 by recommended platform.

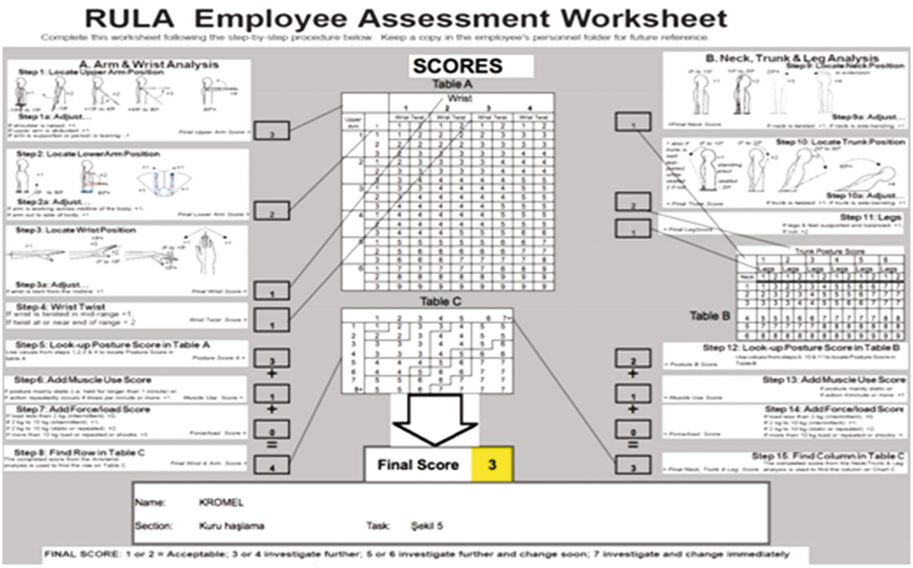

Fig. 13. Improved RULA score result of Fig. 5 by recommended chair

The static works and postures that are seen in Fig. 5 should be prevented and placed the sit-stand chair that helps the back and legs and also gives the worker a rest as shown in Fig. 8. The RULA score was improved from 7 to 3 with the recommended chair (Figs. 13, 14). Personal and collective protection measures should be taken for the heat, flares and gases that are exposed as a result of the welding operation shown in Fig. 6. The welding operation should be done behind a portable safety screen to prevent other people working in the same place or should be done in a designated place (like weld cell) with personal protection equipments.

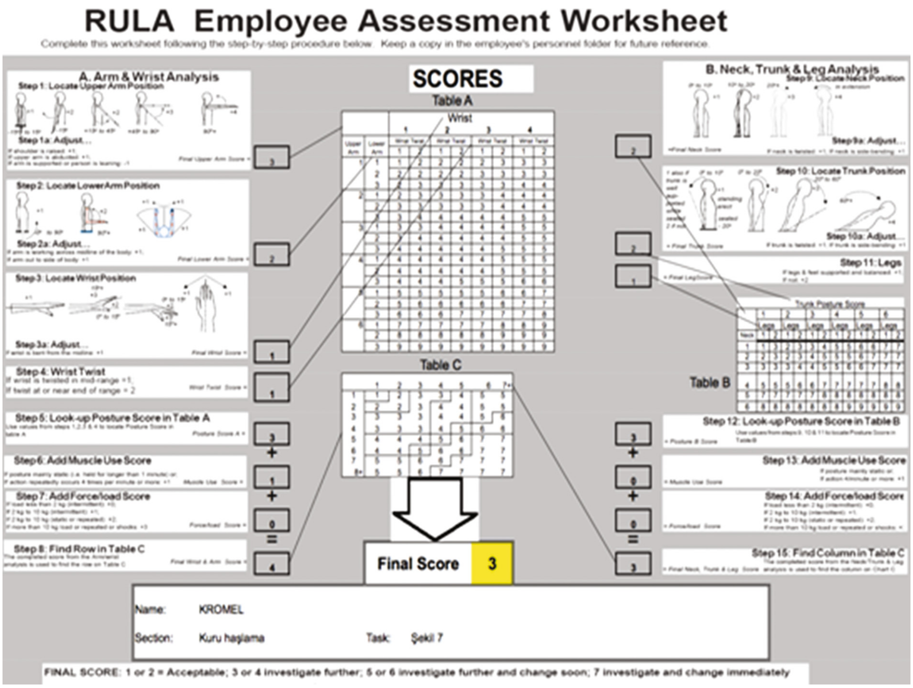

Fig. 14. Improved RULA score result of Fig. 7 by recommended chair.

6 Conclusion

Also the cause of non-ergonomic postures of the worker which include bending and standing on one foot should be prevented by adjusting the height of the pool as shown in Fig. 11. The Rula score result was improved from 7 to 3 by recommended pool height and method as shown in Fig. 14. The height of the pool was adjusted by taking the average leg height of the workers. When working with the pool in order to be open around it, the area to be placed should be identified and marked. Thus bending is prevented and posture is reatined. The adjustable chair also provides support for both the back and the feet as shown in Fig. 8. Also if the adjustable chair working height is not enough for the job, the platform shown in Fig. 9 should use.

There are many small and medium sized enterprises in dairy processing industry. They have project type manufacturing system. Because of variety and size in the products, they cannot standardise over all the process. So, the most complex product that is most-ordered in various sizes is chosed, then its all process and manufacturing area have been examined from an ergonomic point of view. As a result of the review ergonomic deficiencies were found in the enterprise. The working environment is improved from the ergonomic point of view and the productivity of the employees is increased by the recommendations and evaluations. Also, Ergonomic risk analysis is provided with the control of these ergonomic improvements. Net efficiency increase has been proven by comparing work studies measurements on the product before and after ergonomic evaluation.

References

1. Bridger, R.S.: Introduction to Ergonomics. McGraw-Hill Inc, New York (2002)
2. Stephen Pheasant, S., Haslegrave, C.M.: Bodyspace: Anthropometry, Ergonomics and the Design of Work (1996)
3. Foster, Sabancı, A., Sümer, S., Say, S.: Endüstriyel Ergonomi. Nobel Akademik Yayınevi, Ankara (2012)
4. Güler, Ç.: Sağlık boyutuyla Ergonomi, pp. 291–314. Palme Yayınevi, Ankara (2004)
5. Dul, J., Weerdmeester, B.: Ergonomi, Ne, Neden, Nasıl, Çeviren. In: Yavuz, M., Kahraman, N., Kitabevi, S. (eds.) Ankara (2007)
6. Urlings, I.J.M., Nuboer, I.D., Dul, J.: A method for changing the attitudes and behaviour of management and employees to stimulate the implementation of ergonomic improvement. Ergonomics **33**, 629–637 (1990)
7. Mirka, G.A., Smith, C., Shivers, C., Taylor, J.: Ergonomic interventions for the furniture manufacturing industry: part I e lift assist devices. Int. J. Ind. Ergon. **29**, 263–273 (2002)
8. Akay, D., Dağdeviren, M., Kurt, M.: Çalışma Duruşlarının Ergonomik Analizi. J. Fac. Eng. Archit. Gazi University **18**(3), 73–84 (2003). CILT
9. Sutton, I.: Human Factors and Ergonomics, Plant Design and Operations, pp. 160–177 (2015)
10. Sabancı, A., Korkut, S.S.: Ergonomi. Nobel Kitabevi, Ankara (2011)
11. Erkan, N.: Ergonomi. MilliProdüktiveMerkezi Yayınları, Ankara (2001)
12. Babalık, F.C.: Mühendisler için Ergonomi-İşbilim. Dora Yayınları, s.377 (2011)
13. Heskett, J., Tasarım, Kültür Kitaplığı 131, Dost Kitabevi Yayınları, s.75 (2002)
14. Parkes, K.R., Carnell, S., Farmer, E.: Research Report on Musculoskeletal Disorder, Mental Health and Work Environment. Health and Safety Executive. University of Oxford, Oxford (2005)
15. Yelin, E.H., Trupin, L.S., Sebesta, D.S.: Transitions in employment, morbidity and disable among persons aged 51 to 61 with musculoskeletal and non-musculoskeletal conditions in U.S., 1992–1994. Arthitis Rheum. **42**, 769–779 (1999)
16. Praemer, A., Furner, S., Rice, D.P.: Musculosketal Conditions in the United States. American Academy of Orthopaedic Surgeons, Rosemont (1999)
17. Schierhout, G.H., Myers, J.E., Bridger, R.S.: Musculoskeletal pain and workplace ergonomic stressors in manufacturing industry in South Africa. Int. J. Ind. Ergon. **12**(1–2), 3–11 (1993)

18. Waters, T.R.: National efforts to identify research issues related to prevention of work-related musculoskeletal disorders. J. Electromyogr. Kinesiol. **14**, 7–12 (2004)
19. Jaffar, N., Abdul-Tharim, A.H., Mohd-Kamar, I.F., Lop, N.S.: A literature review of ergonomics risk factors in construction industry. Procedia Eng. **20**, 89–97 (2011)
20. Kazutaka, K.: participatory methods effective for ergonomic workplace improvement. Appl. Ergon. **37**(4), 547–554 (2006)
21. Kaya, Ö.: Design of work place and ergonomics in garment enterprises. Procedia Manufact. **3**, 6437–6443 (2015)
22. Kushwaha, D.K., Kane, P.V.: Ergonomic assessment and workstation design of shipping crane cabin in steel industry Int. J. Ind. Ergon. **52**, 29–39 (2016)
23. Sutalaksana, I.Z., Widyanti, A.: Anthropometry approach in workplace redesign in Indonesian Sundanese roof tile industries. Int. J. Ind. Ergon. **53**, 299–305 (2016)
24. Özcan, E., Kesiktaş, N.: Mesleki kas iskelet hastalıklarından korunma ve ergonomi. İş Sağlığı ve Güvenliği Dergisi **34**, 6–9 (2007)
25. Jurgens, H.W., Aune, L.A., Pieper, U.: International Data on Anthropometry, Occupational Safety and Health Studies. International Labour Office, Geneva (1990)
26. Koca Özer, B.: Secular trend in body height and weight of Turkish adults. Anthropol. Sci. **116**(3), 191–199 (2008)
27. Şaşmaz, T., Öner, S., Buğdaycı, R., Kurt, A.Ö., Öner, H., Güler, Ç.: Büro Ergonomisi. Editör Güler Ç. Sağlık Boyutuyla Ergonomi Hekim ve Mühendisler İçin. Palme Yayıncılık, Ankara, s. 345–361 (2004)
28. McPhee, B.J.: Work-related musculoskeletal disorders of the neck and upper extremities in workers engaged in light, highly repetitive ivork'. In: Osterholz, U., Karmaut, W., Hullma, B., Ritz, B. (eds.) Proceedings of Irzt Symposium Work Related Musculoskeletal Disorders, Bonn, pp. 244–258 (1987)
29. Das, B., ve Sengupta, A.K.: Industrial workstation design: a systematic ergonomics approach. Appl. Ergon. **27**(3), 157–163 (1996). CILT

Ergonomic Value Stream Mapping: A Novel Approach to Reduce Subjective Mental Workload

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Abstract. Recently, companies have become more interested about well-being and satisfaction of human resources. There is an increased awareness that conditions on the marketplace such as high variety products, demand fluctuations and the high service levels required by customers make it necessary to develop methods and models to measure and predict human performance. As Lean Manufacturing is a popular method used at companies in order to foster productivity and innovation in the industrial environment, we proposed the application of the Ergonomic Value Stream Mapping, a novel tool that aims to improve ergonomic conditions while productive performance indicators are also in focus. This work aims to provide academics and practitioners with a novel tool capable to satisfy current needs in manufacturing environments, regarding cognitive ergonomics assurance at workplaces. The implementation of ErgoVSM on its cognitive modality is an effort for acknowledging the significance of assessing health risks within each workstation at companies.

Keywords: Cognitive ergonomics · Subjective mental workload · ErgoVSM · Lean manufacturing

1 Introduction

Over years, lean manufacturing has provided significant positive results in a wide range of companies, reducing waste and improving productivity; therefore, it is very likely that will continue to grow and become an important aspect for many industries [1]. However, current research recognize that rationalization tools such as lean generally have a negative effect on health, risk factor [2] and result in work intensification [3]. Yet, some authors have detected that the lean approach needs to detect situations where the ergonomic aspect is poor or exist potential improvements. Researchers are aware of the possible impacts on employee's productivity, reducing the efficiency on creating value during a formal job shift [4].

Current conditions in modern manufacturing, such as providing a wide range of product variety and the established short lead-times, require operators to use higher cognitive skills to complete a task successfully, which makes the Mental Workload much higher than assembling a single product, and therefore easily leading to an increase in human errors. On the other hand, when correctly acknowledged, Mental

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Workload can improve product quality and guarantee the efficiency simultaneously [5]. Subjective Mental Workload (SMWL) refers to the amount of effort done by the mind during an individual function, and is related to an individual's mental capacity [6]. Assessment of SMWL is one of the main goals of ergonomics aiming at investigate and improve the human–machine relationship and achieving convenience and satisfaction in the workplace [7].

Recent investigation aims to both, improve work conditions and reduce wastes, resulting on higher productivity and profits. A novel tool that attempts to integrate ergonomics and lean techniques is the so-called Ergonomic Value Stream Mapping (ErgoVSM), which has proved to be useful for engineers and experienced operators by estimating ergonomic improvements of proposed processes without any negative effects on the estimated production performance [8]. ErgoVSM incorporates aspects of the physical and psychosocial work environment into the lean tool VSM [9].

Previous works on this field analyzed the gains of considering the significant role of ergonomics in the rationalization of the work. However, none of them, to the best of our knowledge, comprises Mental Workload; even more, authors recognize that psychosocial factors of importance to health and well-being should be included in the tool [8]. This research presents a dual assessment of feasibility, taking into account both the performance metrics typically used in VSM, and the SMWL, which is valuable for both academics and practitioners to foster research in this field and improve current productive practices.

2 Literature Review

2.1 Overview of the Lean Approach

Lean manufacturing has its origins in the Toyota production system and it consists of a method to systematically reduce waste and maximize value in manufacturers [10]. The seven sources of waste that it identifies are: over-production, waiting time, transportation, over-processing, inventory, motion, and scrap [11, 12]. This approach has become very popular among manufacturers, services and large commercial areas [13]. Nowadays, it is so far the most widely known method for industrial improvement [14] and acts on improvement work through a set of group activities that pursue the benefit the organization [15].

Aiming to support and encourage the adoption of lean, many tools have been developed and adapted to different types of industries and manufacturing environments over time; this is possible due to its multi-dimensional perspective [16]. Some of the techniques and concepts commonly applied are: VSM, Gemba walks, JIT, kaizen events, production preparation process (3p), cellular manufacturing, single-minute exchange of dies, total productive maintenance, poka-yoke mechanisms, among others [17].

Lean tools and practices have provided companies with significant help at facing the waste challenge, thus, it has been possible to foster productivity and other key performance indicators. There are several cases where authors have reported positive results after implementation, such as shortening lead-times [18, 19], reduce work-in-process inventories [10, 20] increase of the value-added ratio [21] and many others. On the other hand, authors have perceived a negative side effect as product of the way in which lean manufacturing practices are applied. Among these impacts are the lack of capability of some of the tools to quantify and manage uncertainty, as well as to address the benefits of these tools under a dynamic perspective [16, 22]. Additionally, it has been found that lean methods affect the risk factors at workplaces, which might be dangerous for employees as it increases the repetitiveness and the mental workload [2, 3].

2.2 The Role of Ergonomics within Lean Manufacturing Systems

The lean manufacturing system is complex and benefic but the possible changes may cause ergonomical issues [23]. Human resources, the most important element in an organization, often feel the problems that arose in this regards. It is very important to consider that lean manufacturing system has more than one face and this makes the interpretation of its impact complex, therefore it is necessary to assess each of the important aspects before any transformation of the productive system, including ergonomics [24]. Ergonomic interventions attempt to improve physical and/or psychosocial working conditions for the individual while rationalization prioritizes creation of value at the facilities. Thus, ergonomists, working within a health paradigm, and production engineers, devoted to improving system performance, may have conflicting objectives [25].

Some authors have reported results as product of ergonomic assessments in after implementation of lean manufacturing techniques; these results include positive feedback such as an increase of workers autonomy [26, 27] and a decrease of hierarchical levels [28]. On the other hand, there have been found negative impacts along with the implementation of lean, including an increase of stress levels [29, 30], as well as work intensification [26, 31]. This available research allow us to see the importance of control and verify the well-being of the human resources has to be periodically.

2.3 ErgoVSM in Literature

ErgoVSM is based on the regular VSM methodology proposed by Rother and Shook [32]. While traditional VSM consists of drawing the current and future state of the productive system in order to eliminate sources of waste as much as possible [33], ErgoVSM it includes an ergonomic complement [3, 8]. Literature shows that the application of ErgoVSM is beneficial for improving ergonomic conditions without any negative effects on the estimated production performance [8]. However, even though ErgoVSM forces the employees to evaluate their work environment, a study states that it is not possible to conclude that those improvements are due the use of this tool [3]. Yet, there is another author, who suggest that ErgoVSM facilitates the development of an action plan that may result in higher organizational sustainability compared with VSM, based on preliminary data [9].

Available papers about ErgoVSM focus mainly on the assessment of physical issues, such as musculoskeletal disorders. Although some exemplary instructions are given on evaluation of mental demands, control/influence and communication, to the best of our knowledge available research has not specifically addressed the SMWL in previous case studies [34].

2.4 Subjective Perspective on Ergonomic Assessments

There are many subjective procedures and instruments to assess mental workload, three of the most outstanding among them are the NASA Task Load Index (TLX), the Subjective Workload Assessment Technique, and the Workload Profile [35]. The NASA Task Load Index [36] evaluates six dimensions in regads of mental workload: mental demand, physical demand, temporal demand, performance, effort, and frustration. The Subjective Workload Assessment Technique uses three levels: (1) low, (2) medium, and (3) high, for each of three dimensions of time load, mental effort load, and psychological stress load to assess workload. Workload Profile tries to combine the advantages of secondary task performance based procedures (high diagnosticity), subjective techniques (high subject acceptability and low implementation requirements and intrusiveness [37].

The NASA-TLX instrument was selected for this study, after considering that it has been utilized in a wide range of areas, including military, government [38] and banking staff [7]. Additionally, it is very portable and can be used in operational experiments; it is reasonably easy to use [39] and reliably sensitive to experimentally important manipulations over the past 30 years [38].

2.5 Subjective Perspective on Ergonomic Assessments

The use of this instrument consists of two parts: ratings and weights. Ratings for each of the six subscales are obtained from the subjects following the completion of a task. A numerical rating ranging from 0 to 100 is assigned to each subscale. Then, weights are determined by the subjects' choices of the subscale most relevant to workload for them from a pair of choices. After that, the weights are calculated from the tally of these choices from 15 combinatorial pairs created from the six subscales. The weights range from 0 to 5 (least to most significant). The ratings and weights are then combined to calculate a weighted average for an overall workload score [39].

3 Methods

Even though it is possible to apply this study to any type of hazard, we focused on the SMWL, considering this of a great value because Ergo-VSM has not been previously applied to this kind of assessment. Moreover, we chose this evaluation due to the characteristics of the tasks performed at the workstations. This will be a bi-objective study with focus on fostering both productivity and ergonomic factors at the workplace. In this case, we selected a group of group lean tools that have proved to be resilient in the manufacturing environment along with the instrument NASA TLX to assess SMWL within the facilities.

Firstly, one designated person will create the Ergo-VSM, as the methodology of the traditional tool indicates, although this will include the values for the evaluation of the SMWL. The selected techniques will be used in the following order: Ergo-VSM, kaizen event, Gemba walk, 3p, aiming to propose a feasible option for redesigning the work area. During the elaboration of the Ergo-VSM, relevant information will be collected and depicted in the current state map. Then, the same information used for the creation of the future state of the Ergo-VSM.

Once the maps have been created, the team members of the project will met in form of a kaizen event in order to develop an improvement proposal collectively. As part of this event, the members will perform Gemba walks on the production floor to detect anomalies, and then, a 3p will be carried out by the members. The goal will be to redesign the workstation aiming to improve the key performance indicators such as inventories and productivity, while decreasing the SMWL.

To perform the SMWL evaluation of both current and future state, we will use the physical version of the NASA TLX instrument among the operators. After talking with employees in order to make them aware of the goals and the relevance of the project, they will be required to fill up the information in the form shown in Fig. 1, followed by some questions, as part of the instrument.

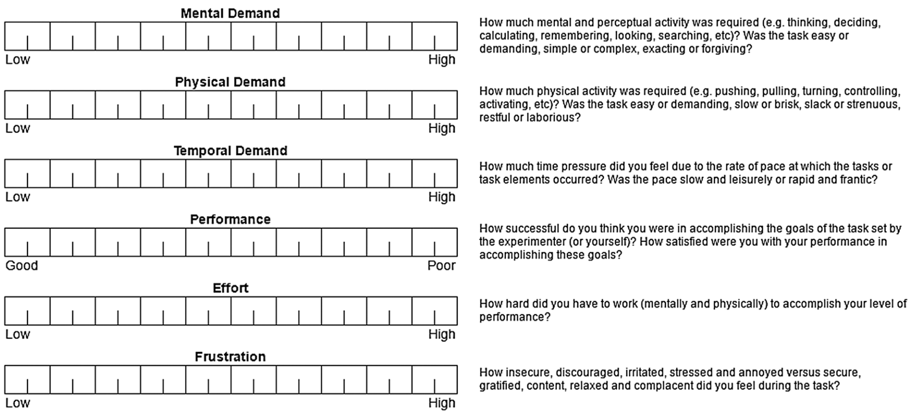

Fig. 1. Nasa-TLX rating scale.

Once the proposals obtained as result of the 3p methodology have been developed, the action plan will be presented to the management level for approval and the model will be implemented in the production floor, to verify that the previously simulated results correspond to reality, and adjust the physical distribution or production pace if necessary. The process herein present must be developed with a continuous improvement approach, in order to sustain and foster progress.

4 Case Study

Taking into account the ergonomic and lean manufacturing principles, we pursued a significant improvement aiming to potentiate wastage reduction and increase productivity, while reducing SMWL. This project was conducted at a real production system, where all the above techniques and tools were put into practice as part of one single project.

4.1 Company Background

The company considered for this project will be called XYZ due to confidentiality purposes. It is located in the north of Mexico. This is a global company certified in ISO 9000 with several departments and workstations, where it produces electronic components for industries such as defense, healthcare, and automotive, among others. We worked at a specific department with a single product family (a set of products sharing similar processes). According to the employees and manufacturing engineer of this area, it had productivity issues since approximately eleven years ago; these situations refer specifically the great amount of idle time perceived and ineffective work distribution among operators. Even though they knew the importance of provide solutions to the deficient productivity of the area, this recently became urgent due to new management strategies.

4.2 Implementation

The team the project was integrated by eight persons from different hierarchy levels, ranging from operators, shift leaders, process, production, quality and manufacturing engineers, as well as a manager and an external researcher. Firstly, the Ergo-VSM was developed with help of the external researcher, taking into account each of the significant indicators along the entire value stream at a door-to-door level of the selected product family. In order to perform the maps of both the current and future state, it was necessary the support and commitment of several areas, such as planning, purchasing and procurement of materials. Then, the SMWL evaluations were carried out preceded by an introductory talk about the goals and relevance of the project to all the operators of the area. The resulting maps including lean and ergonomic indicators can be observed in Figs. 2 and 3.

After the important information was available and ordered, it was presented to the team members and a kaizen event was arranged, with focus on generating ideas that could potentially achieve both objectives pursued. The team was divided into smaller groups in order to perform Gemba walks and remark possible areas of improvement; then, it was necessary to adjust the Ergo-VSM, since as the VSM methodology indicates, some important aspects became noticeable afterwards. Some of the problems observed were the accumulation of work-in-process inventories, the malfunction of the press and bad distribution of work content among operators.

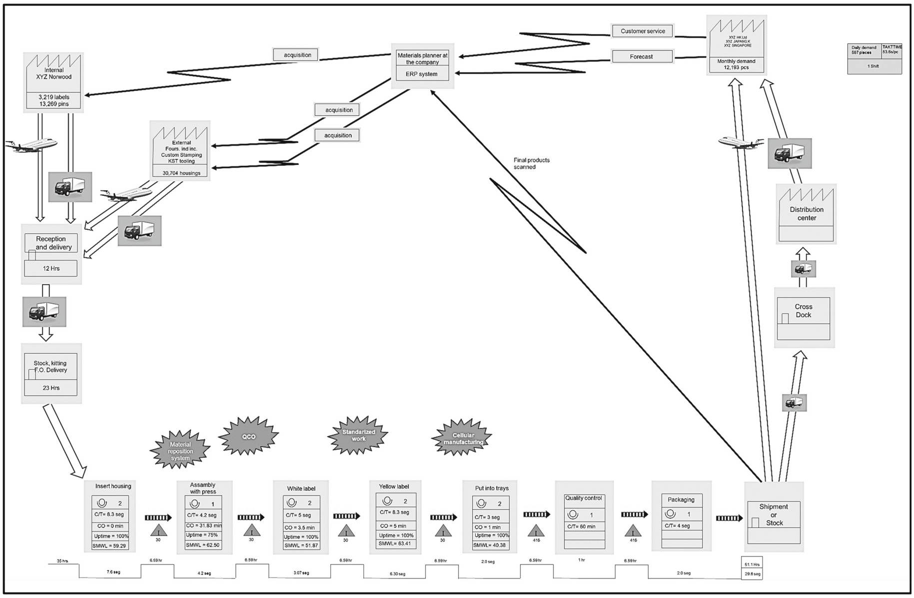

Fig. 2. Ergo-VSM on its current state.

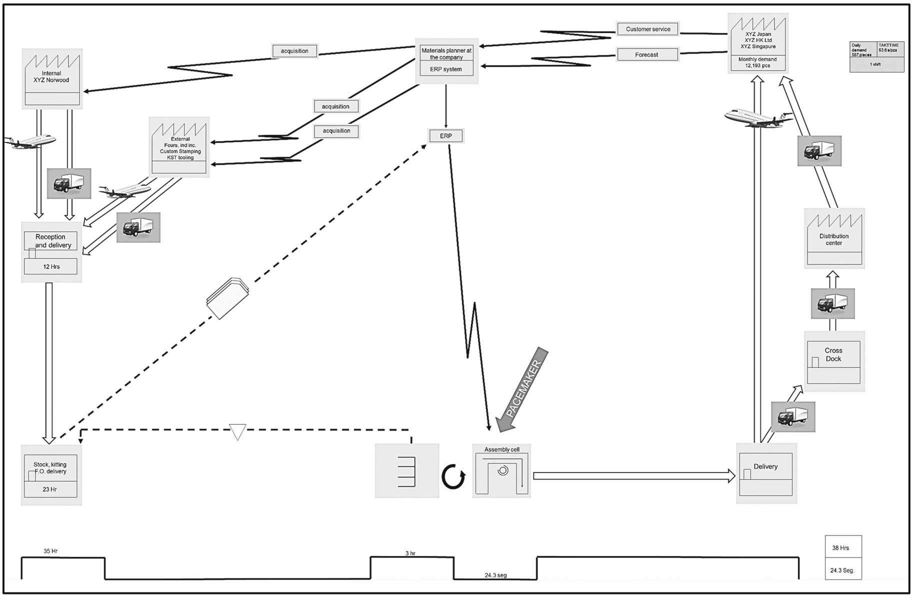

Fig. 3. Ergo-VSM on its future state.

Fig. 4. Engineer and operators implementing 3P tool (sketching examples).

The team followed the 3p technique aiming to propose a workstation redesign capable to deliver better results in both ergonomic and productive aspects. As part of the 3p methodology, the members collaborated in the construction of a prototype of the new workstation that included the potential improvements t. They first remarked the goal of the prototype and give keywords to achieve it, such as quality, order, safety, teamwork, among others. Then, each of the members sketched examples using paper and pencil, and shared their ideas with the rest of the team as shown in Fig. 4.

The stakeholders reached a common proposal, which acknowledge productivity, as well as ergonomic aspects. The selected design was then drawn by one of the members and verified by the rest of them. Right after, they constructed the prototype using recycled objects such as carton boxes available at the facilities, cardboard, sticky tape and similar materials. The redesigned the layout and distribution of work, aiming to

Fig. 5. Final 3p design prototyped

improve the flow of materials and reduce the SMWL indicator. This was tasted and adjusted, and several simulations of the assembly process were carried out, until the team approved the prototype (Fig. 5).

5 Results and Conclusions

The application of the selected lean tools showed us that all of the operators within the analyzed area have experienced excessive mental workload regularly during the performance of the tasks. The activity more demanding was press assembling, for which the NASA-TLX estimated weight of each of the factors that integrates SMWL. The highest scores were observed on Performance and Mental Demand scales with mean $\pm$ SD of 84.95 $\pm$ 7.18 and 75.71 $\pm$ 6.94, respectively.

After simulating the potential improvements approved by the team members, results showed a decrease on the SMWL from an average overall score of 59.29 in the current state, to 42.56 in the future state. The changes to be applied as part of the action plan include materials reposition system for reduction of inventory; layout redesign, with the transformation to a cell manufacturing system; and the redistribution of the work among operators according to the takt time. The results obtained after simulation can be observed in Table 1.

Table 1. Obtained results after 3p simulation

	Current	Proposed	Improvement (%)
Space (sq/ft)	240	80	67
Number of operators	7	1	86
Productivity (pcs/hr/op)	43	148	244
Work in process (pcs)	952	1	99.9
Overall SMWL	59.29	42.56	28.2

The conducted case study does not show any drawback derived from the consideration of ergonomic assessments as part of the lean activities. Although this type of additional analysis require a significant amount of time, it might result in future savings for companies, since it is much more feasible and useful to take into account ergonomic factors before applying physical transformations in productive systems. We would like to encourage future research on this field by conducting further works, which continue to evaluate the effects of performing sustainable improvement activities within companies.

References

1. Cox, C., Ulmer, J.: Lean manufacturing: an analysis of process improvement techniques. Franklin Bus. Law J. **2**, 70–77 (2015)
2. Westgaard, R., Winkel, J.: Occupational musculoskeletal and mental health: significance of rationalization and opportunities to create sustainable production systems - a systematic review. Appl. Ergon. **42**(2), 261–296 (2011)

3. Edwards, K.: Ergonomic value stream mapping – can lean and ergonomics go hand in hand? In: Human Factors in Organizational Design and Management, vol. XI, pp. 123–126 (2014)
4. Romero Dessens, L.F., Chávez López, Z.I.: Use of value mapping tools for manufacturing systems redesign. In: Industrial Engineering: Innovative Networks. Springer, London (2012)
5. Zhao, X., Hsu, C.Y., Chang, P.C., Li, L.: A genetic algorithm for the multi-objective optimization of mixed-model assembly line based on the mental workload. Eng. Appl. Artif. Intell. **47**, 140–146 (2016)
6. Marras, W., Karwowski, W.: Subjective scales of effort and workload assessment. In: Fundamentals and assessment tools for occupational ergonomics, 2nd edn. CRC Press, Boca Raton 2006. p. sec 37–7
7. Darvishi, E., Maleki, A., Giahi, O., Akbarzadeh, A.: Subjective mental workload and its correlation with musculoskeletal disorders in bank staff. J. Manipulative Physiol. Ther. **39**(6), 420–426 (2016)
8. Jarebrant, C., Winkel, J., Johansson Hanse, J., Mathiassen, S.E., Öjmertz, B.: ErgoVSM: a tool for integrating value stream mapping and ergonomics in manufacturing. Hum. Factors Ergon. Manuf. Serv. Ind. **26**(2), 191–204 (2016)
9. Gunnarsdóttir, S., Dröfn Birgisdóttir, B.: Ergonomic value stream mapping (ErgoVSM) – potential for integrating work environment issues in a Lean rationalization process at the University Hospital on Iceland. In: 7th NOVO Symposium: A Nordic Model for Sustainable Systems in the Health Care Sector, p. 14 (2013)
10. Bertolini, M., Braglia, M., Romagnoli, G., Zammori, F.: Extending value stream mapping: the synchro-MRP case. Int. J. Prod. Res. **51**(18), 5499–5519 (2013)
11. Hines, P., Rich, N.: The seven value stream mapping tools. Int. J. Oper. Prod. Manag. **17**(1), 46–64 (1997)
12. Steur, H.D., Wesana, J., Dora, M.K., Pearce, D., Gellynck, X.: Applying value stream mapping to reduce food losses and wastes in supply chains: a systematic review. Waste Manag. **58**, 359–368 (2016)
13. Arezes, P.M., Dinis-Carvalho, J., Alves, A.C.: Workplace ergonomics in lean production environments: a literature review. Work **52**(1), 57–70 (2015)
14. Dotoli, M., Epicoco, N., Falagario, M., Costantino, N., Turchiano, B.: An integrated approach for warehouse analysis and optimization: a case study. Comput. Ind. **70**, 56–69 (2015)
15. Alpenberg, J., Scarbrough, D.P.: Exploring communication practices in lean production. J. Bus. Res. **69**(11), 4959–4963 (2016)
16. Abdulmalek, F., Rajgopal, J.: Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study. Int. J. Prod. Econ. **107**, 223–226 (2007)
17. Ar, R., Al-Ashraf, M.: Production flow analysis through value stream mapping: a lean manufacturing process case study. Procedia Eng. **41**, 1727–1734 (2012)
18. Abuthakeer, S., Mohanram, P.V., Kumar, G.: Activity based costing value stream mapping. Int. J. Lean Thinking **1**(2), 51–64 (2010)
19. Dushyanth Kumar, K.R., Shivashankar, G.S., Rajeshwar SK: Application of value stream mapping in pump assembly process: a case study. Ind. Eng. Manage. **4**, 162 (2015). doi:10.4172/2169-0316.1000162
20. Lacerda, A.P., Xambre, A.R., Alvelos, H.M.: Applying value stream mapping to eliminate waste: a case study of an original equipment manufacturer for the automotive industry. Int. J. Prod. Res. **54**(6), 1708–1720 (2016)
21. Chong, M.Y., Chin, J.F., Loh, W.P.: Lean incipience spiral model for small and medium enterprises. Int. J. Ind. Eng. **20**(7/8), 487–501 (2013)
22. Schönemann, M., Kurle, D., Herrmann, C., Thiede, S.: Multi-product EVSM simulation. Procedia CIRP **41**, 334–339 (2016)

23. Vieira, S.D.S., Badke-Schaub, P., Fernandes, A.: Framework of awareness: for the analysis of ergonomics in design. Procedia Manufact. **3**, 5955–5962 (2015)
24. Arce, A., Angulo, J., Garcia, V., Quijada, M., Leon, J.: Redesign of workstations to reduce ergonomic risk factors in a electronic manufacturing company. Ergonomía Ocupacional Investigaciones y Aplicaciones **9**, 202–213 (2016)
25. Wells, R., Mathiassen, S.E., Medbo, L., Winkel, J.: Time—a key issue for musculoskeletal health and manufacturing. Appl. Ergon. **38**(6), 733–744 (2007)
26. Genaidy, A., Karwowski, W.: Human performance in lean production environment: critical assessment and research framework. Hum. Factors Ergon. Manufact. Serv. Ind. **13**(4), 317–330 (2003)
27. Parker, S.K.: Longitudinal effects of lean production on employee outcomes and the mediating role of work characteristics. J. Appl. Psychol. **88**(4), 620 (2003)
28. Saurin, T.A., Ferreira, C.F.: The impacts of lean production on working conditions: A case study of a harvester assembly line in Brazil. Int. J. Ind. Ergon. **39**(2), 403–412 (2009)
29. Kazmierczak, K., Winkel, J., Westgaard, R.H.: Car disassembly and ergonomics in Sweden: current situation and future perspectives in light of new environmental legislation. Int. J. Prod. Res. **42**(7), 1305–1324 (2004)
30. Conti, R., Angelis, J., Cooper, C., Faragher, B., Gill, C.: The effects of lean production on worker job stress. Int. J. Oper. Prod. Manag. **26**(9), 1013–1038 (2006)
31. Carayon, P., Smith, M.J.: Work organization and ergonomics. Appl. Ergon. **31**(6), 649–662 (2000)
32. Rother, M., Shook, J.: Learning to See: Value Stream Mapping to Add Value and Eliminate Muda, 2nd edn. Lean Enterprise Institute, Brooklin (1999)
33. Li, X.: A Literature Review on Value Stream Mapping With a Case Study of Applying Value Stream Mapping on Research Process. Texas A&M University, Texas (2014)
34. Jarebrant, C., Johansson, H., Harlin, U., Ulin, K., Winkel, J., Edwards, K., Birgisdóttir, B.D., Gunnarsdóttir, S.: Ergonomic Value Stream Mapping: Tool and User guide. Nordic Council of Ministers, Copenhagen (2016)
35. Rubio, S., Díaz, E., Martín, J., Puente, J.M.: Evaluation of subjective mental workload: A comparison of SWAT, NASA-TLX, and workload profile methods. Appl. Psychol. **53**(1), 61–86 (2004)
36. Hart, S.G., Staveland, L.E.: Development of NASA-TLX (Task Load Index): results of empirical and theoretical research. Adv. Psychol. **52**, 139–183 (1988)
37. Tsang, P., Johnson, W.: Cognitive demand in automation. Aviat. Space Environ. Med. **60**, 130–135 (1989)
38. Hart, S.G.: NASA-task load index (NASA-TLX); 20 years later. Proc. Hum. Factors Ergon. Soc. Ann. Meet. **50**(9), 904–908 (2006)
39. Cao, A., Chintamani, K.K., Pandya, A.K., Ellis, R.D.: NASA TLX: software for assessing subjective mental workload. Behav. Res. Methods **41**(1), 113–117 (2009)

An Ergonomic Interventional Approach to Improve Office Workspace for Policewomen in Assam, India

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Abstract. Enhanced workstation is a prerequisite to escalate productivity, the same being applicable for the women police personnel involved in law-and-order enforcement. The paper deals with how the well-being of the women police at workplace was perceived after implementation of proposed ergonomic intervention. The study was conducted with existing All Women Police Station and other Police Stations in Guwahati, Assam, India, considering their occupational stress and hazards. In this descriptive study a sample of 30 women police was selected by purposive sampling and analyses were performed using responses to a questionnaire method and individual/group meetings. The aim of the study is to be look into office workstation design of police station with reference to womanhood specific issues to enrich occupational wellness of the women police personnel. Hence the improved atmosphere of workplace upsurges the probabilities of innovativeness, accomplishment and enhances the eminence of work productivity of Policewomen.

Keywords: Policewomen · Workstation modification · Occupational Well-being · On-job satisfaction · Ergonomic intervention

1 Introduction

Over the preceding years, workplace has become an abundantly diverse environment. Organizations of all the domains across the globe are gradually envisaging their workplace approaches with due concern for women working within. Inadequate work place space and uncompromising work requirements contribute to reduced job satisfaction due to greater work pressure for any establishment. Flexible workspace strategies are crucial in order to accommodate the progressive upsurge of modular workstations with involvement of women. Today's generation of employees deserve malleable office environments with employee-friendly job circumstances and policies. The workstation currently trends on speedy organizational changes into progressive and flexible work culture. Occupational well-being observes the need to retain pace with the rapid deviations in office-based work. Working at office (workstation) with awkward postures or for long periods can cause pain, discomfort and injury.

Policing has so far been a predominantly male's job globally. Engagement of women in law enforcement started merely in the early twentieth century in a very lesser

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records [1]. Progressive induction of women in law and enforcement is gradual in a phased manner (in terms of government rules and policies). Women have diverse capabilities and authenticities than men [1]. Woman police could bring superfluous services and potentials, and upsurge the image of, and communal self-assurance in the police.

In India, women comprise 24.4% of the overall workforce, where safety has become essential to their physical, professional, intellectual and emotional well-being in their work place [2]. Lots of innovative fields are escalating fast and it is essential to accommodate the women police personnel in those domes. The timeworn inclinations should be set distinctly to set out for first-hand opportunities and potentials of improvement and accomplishment through more engrossment of women in workplace. The impression of women in law enforcement is attaining position throughout the world, and numerous nations are tapping intense determinations to mainstream women in policing.

Subsequently, the outcome of workspace at police station on the employee efficiency has been efficaciously reflected as a critical contributor to their satisfaction leading to healthier effective inspiration. In light of these, the present research aimed to look into the office workstation design of police station with reference to occupational well-being of the women police personnel through ergonomic design interventions. This study also explored how workplace environment of police stations build complications and difficulties for women police personnel and adverse impact in the efficiency of policewomen.

2 Methodology

The present study, being a descriptive research and review in nature, was grounded on primary data as well as secondary data. A survey was administered on thirty (n = 30) women police personnel of different ranks posted in Guwahati (All women Police Station of Pan Bazar, Guwahati, Assam), chosen by purposive non-probability sampling, subsequently elucidating them the purpose of the study and obtaining individual written informed consent. The design of the study endeavoured to assess the psycho-social/physical hazards, awkward posture and work environment along with occupational concerns, and the stress divulged thereby on the policewomen in their workplace, also extended to their outstation duties like patrolling etc. Personal interview (audio recording with individual informed consent) was conducted to support required information thereby increasing the validity and reliability of responses to the questionnaire; which alone might not be sufficient to have proper perception about the ground situation.

3 Results

The research revealed that policewomen in the AWPS Pan Bazar were suffering from inconveniences and discomforts due to the fact that the design of their workstations was age old. It was also found that that higher authority did not have a preference for workplace comfort in the AWPS. Mostly the respondents reported to suffer from musculoskeletal disorders in the shoulders, arms and neck at the respective workplace considering the physical risk factors in the police station while on duty. Greater body force, repetition, long term static postures, prolonged sitting and standing, exposure to heat and fatigue were among the frequently identified physical risk factors in the police job. Workplace of AWPS, Pan Bazar, Guwahati suffered from low maintenance and which increases the negative consequences thereby reducing the job satisfaction. Subsidence of these risk factors was the major goal to render utmost preventive approaches in the work environment. Several respondents stated that policing is not an easy occupation for females because of insufficient of resources, separate arrangement and amenities and communal gravities [3].

In many of the developing countries it is evident that the office work station design is in the initial stage in police station. The Parliamentary Committee of India on 'Empowerment of Women' also documented the working conditions of women in

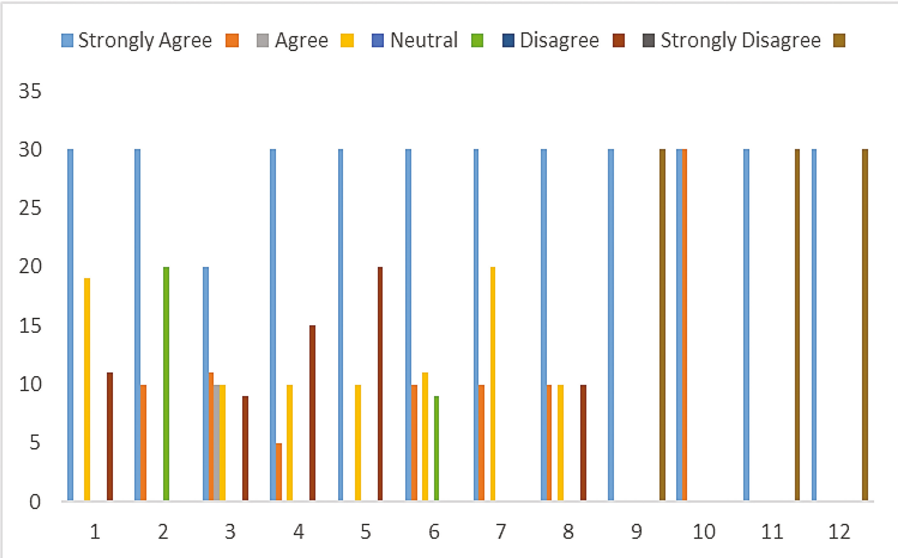

Fig. 1. Results of survey on exposure to occupational and environmental stress and perceived well-being. 1–12 along X-axis represents the questions from the questionnaire developed explained hereafter. 1. Lack of resources cause stress. 2. Shift work causes stress for special cases Like pregnancy, expecting mother, lactating mother, menstruation period. 3. Social life outside the job is impacted by duty regimen. 4. Occupation-related health issues in special cases like pregnancy, expecting mother, lactating mother, menstruation period. 5. Unfair work environment in this job. 6. Inadequate or poor quality equipment/maintenance. 7. Lack of a modern system/apparatus on duty. 8. Occupational health issues (e.g. back pain, neck pain, and joint pain). 9. A good infrastructure brings satisfactions while doing work. 10. Prolong standing affects physical health. 11. Lack of separate modular convenience/prompt service utilities in every police station. 12. Basic amenities like isolated/separate restrooms and child care units are still a major requirement for women police personnel

police force (in its 2013-14 and 2014-15 reports) [4] referring to these lack of facilities for the women. The Committee articulated that, these issues can only be tackled through persistent efforts and constant follow up by the government along with time bound action plans. Figures 1 and 2 depicted the gross responses from 30 policewomen of All Women Police Station, Pan Bazar, Guwahati before (abbreviated as B in the tables) and after (abbreviated as A in the tables) some ergonomic interventions towards the holistic occupational improvement of policewomen.

Analysis of the collected data revealed that office design has a major impact on the policewomen's job satisfaction in the workplace (police station). In this study the workstation was improved in such a way that the set of issues would influence on the individual to safeguard and augment proficiency. Office design such as furniture, noise, temperature, lighting and spatial arrangement were considered. The diverse rudiments of intangible framework have impact on productivity but furniture, temperature and light have greater impact on employee's performance. The factor that distresses most on the output of employees is temperature of workplace, second factor that influences the output at high rate is office furniture [5]. The prime feature which pretentious the efficiency of policewomen was the furniture used in the workspace, which was found to be disrupt every day and overall productivity of policewomen.

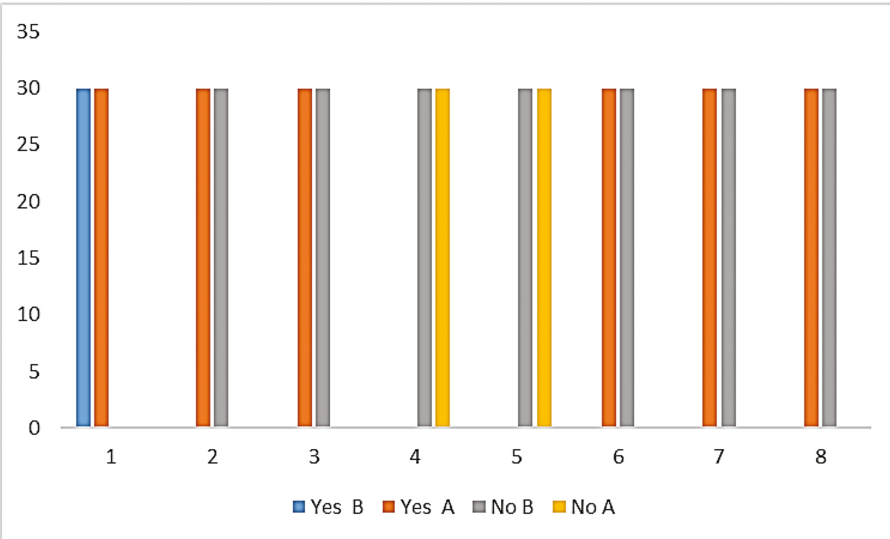

Fig. 2. Survey Results On On-job Satisfaction. 1–8 along X-axis represents the questions from the questionnaire developed explained hereafter. 1–8 represents the questions from the questionnaire developed explained hereafter. 1. Public attitude towards women police is uncooperative. 2. Lack of separate utility facilities in police stations. 3. Problems related to occupational health hazards after intervention. 4. Govt accommodation for womanhood related issues. 5. Difficulties faced in upbringing of children – day care centre is essential. 6. Need to have a better working environment in terms of infrastructure. 7. Provision of separate toilet facility at all offices/outpost. 8. A modular mobile convenience facility while outdoor duty an immediate need

Occupational stresses occur due lack of amenities and resources available in the Police station. One of the foremost apprehensions stated by the policewomen is the necessity to improve privacy in the workplace [6, 7]. The survey found the almost all the women police suffers from occupational health hazards like back pain, neck pain, joint pain due unavailability of resources in the workstation like most importantly proper furniture's.

Job satisfaction is an essential module of an organizations for effective and efficient working condition with the factors the reduces the occupational hazards in the workplace. Majority of the women police revealed that they are not satisfied with the workstation that are provided to them. They opined that the lack of such resources makes environment exhaustive, leading to frequent work burnout in their workplace, and various occupational hazards.

4 Discussion

According to CHRI (2015) report [1], physical conditions matter significantly, specifically applicable for the women. Physical work atmosphere is imperative and it has a foremost effect on mental processes of women police personnel. However, a better provision could be arranged to ensure the compliant workflow of the policewomen. Necessary design elements in the police station could certainly upsurge the working condition of the women police personnel, thus increasing the gross wellness of the employee [8].

As police job deems to levy a higher degree of stress as well array of stressful circumstances which can affect their physical, mental and interpersonal relations of a police personnel [9]. The essential characteristic of office accommodation in the police station is conceivable with the provision of a more flexible workplace [10]. Hence it was recommended that the workspace i.e., the police station would be a place of inspiration and ideas rather than a centre for monotonous dispensation activities with addition to this the workstation must provide organisational reconfiguration and be malleable to new ways of working environments.

Police station (in India) is a workplace with limited amenities and facilities. The workplace remains grossly identical for the police station which causes occupational health hazards with all the respondents interviewed. In this study it was revealed that, police department were lagging behind due to lack of resources provided to them. In contrast to this, it was found that in AWPS Pan bazar Guwahati, the existing furniture were not in a condition of reuse and were beyond the scope of economic repair. It was at the end of its economic life and was functionally obsolete to refurbish and hence up gradation with new furniture was necessary for better working conditions of the women police [10]. Average modular furniture should be used accordingly in the workspace so as to reduce grounds on which they feel exhausted in their workplace. Portable furniture was recommended to allow modest workplace reconfiguration and modified layout which are usually efficient and cost-effective.

Understanding regarding ergonomic interventions to reduce musculoskeletal disorders was quite imperative to improve the health hazards and working condition of the women police in their workplace. Musculoskeletal disorders accounted almost all the women police recompense and have repeated strong work-related component for back pain cases. Workplace risk factors such as combination of physical, psychological, and psychophysical has been observed within the respondents. Risk factors for the development of low back pain include (moderately) flexed, laterally bent or twisted trunk postures, high forces on the hands, high one time or accumulated forces on the spine, and vibration [11].

Work and workplace stress is contributing to develop musculoskeletal symptoms in lower back of women police. In this analysis it was initiated that work stress was directly virtual to perceived level of musculoskeletal symptoms which means the higher the work stress the person was more prone to develop musculoskeletal symptoms [12]. The factor that distresses most on the output of employees is temperature of workplace, second factor that influences the output at high rate is office furniture [5]. The work related injuries is significant to identify so that suitable interventions can be encompassed for reducing the work-related musculoskeletal disorders (WMSD). Furthermore, ergonomics comprises interventions intended at enlightening work at both the level of entities and at the level of work organization. Thus ergonomic interventions are recommended to have proper and adequate ergonomics design intervention to improve the office design for better performance. An intense series of personal interviews with policewomen of AWPS and the questionnaires they responded to, explored a grossly varied tendency of sentiments concerning the current scenario in terms of exposure to occupational and environmental stress and perceived wellbeing, and job satisfaction.

5 Ergonomic Interventions

Ergonomic interventions embrace the concern of entire work place, work methods as well as work organization etc. Moreover, ergonomic intervention would probably facilitate the individuals for prevention of various health hazards which may causes due to improper working environment. Present study provided useful ergonomic interventions in AWPS were approached in the police station to maneuver the physical susceptibilities relevant to physical hazards. Questionnaire detail and personnel interviews with working individuals highlights various health issues related musculoskeletal disorders in their workplace as mentioned in result section. During the investigation, poor design and old age furniture, along with improper sitting posture has been found to be a prime reason behind the reported issue. Therefore, an intervention has been proposed to replace their existing furniture with well ergonomically design furniture, which they implemented accordingly (Fig. 3). In addition to it, individuals have been aware about proper sitting posture in order to work comfortably for prolong time. However, posture intervention feedback from individuals is pending which may incorporate in future study.

Analysis of the questionnaire revealed that the police stations have a significant amount of influence on employee's efficiency. If the work environment is virtuous then the women police can achieve stress free workstation and can affect the overall productivity. The workplace before and after implementing ergonomic design interventions was shown in the Fig. 3. Analysis of the situation in AWPS clarify that, before

(a) Office furniture's – then

(b) Office furniture's – now

(c) Office and sitting area – then

(d) Office and sitting area – now

Fig. 3. Ergonomic interventions anticipated for workplace enhancements of Women Police Station, Pan Bazar, Guwahati and some of their implementations towards easing the workplace environment. The figures represent the situations prior to [(a), (c)] and after [(b), (d)] ergonomic intervention.

the intervention the space was too clumsy, lacking proper sitting area with an age old furniture and after intervention fully modernised furniture at office, sitting area and counselling desk were allotted in the workplace for better working conditions of the women police personnel.

6 Conclusion

As in other countries, policing in India is in crucial need of overall improvement. Nevertheless, there is an imperative requirement to dedicate precise courtesy to the dilemma of women in the police. The insight that establishes in departmental policies and performs must be documented and addressed immediately. The lack of facilities those are vital to ensure an admirable and flexible workplace for women: from basic amenities, to shift system, lack of proper equipment and maintenance, malleable office environments, employee-friendly etc. which enable them to more easily balance work and family responsibilities.

7 Significance of the Study

This type of study is today's need-of-the-hour to empower women and facilitate their inner talent to come up in service of the nation. The office workspace design also finds critical importance for perhaps every occupation, where office workstation needs further improvement. Also the study recommended that government should boast additional consideration to make an amiable workplace environment for the law enforcement to raise productivity and whole organizational performance.

References

1. Commonwealth Human Rights Initiative (CHRI), Rough Roads to Equality Women Police in South Asia (2015). http://www.humanrightsinitiative.org
2. FICCI & FLO Industry Task Force on Safety of Women at Work Place, Safety of Women at the Workplace Recommendations for Businesses. http://ficci.in/SEdocument/20249/Safety-of-women-at-workplaces-Recommendations-for-Businesses.pdf
3. Haider, A.: Needs and Challenges for Women Police: Study of Islamabad Capital Territory (ICT) Police, Department of Development Studies Discussion Paper 4, pp. 1–10, December 2015
4. Lok Sabha Publications. Committee of Women empowerment: First (2013-2014) and second (2014-2015) report on "Working Condition of Women Police". Lok Sabha, Delhi Secretariat (2015)
5. Akhtar, N., Ali, S., Salman, M., Asad-Ur-Rehman, Ijaz, A.: Interior design and its impact on of employees' productivity in telecom sector, Pakistan. J. Asian Bus. Strategy **4**, 74–82 (2014)
6. Bora, S., Chatterjee, A., Rani, P., Chakrabarti, D.: On-the-job stress: interventions to improve the occupational well-being of policewomen in Assam, India. J. Int. Women's Stud. **18**(1), 260–272 (2016). http://vc.bridgew.edu/jiws/vol18/iss1/16
7. Women in police face privacy, sanitation issues at work: Survey. http://economictimes.indiatimes.com/news/politics-and-nation/women-in-police-face-privacy-sanitation-issues-at-work-survey/articleshow/50887809.cms
8. Devare Phadke, S.S., Iqbal, R.: Review article work place design reforms for traffic police. Int. J. Curr. Res. **8**(1), 25493–25495 (2016)
9. Sekar, M., Subburaj, A., Shunmuga Sundaram, M.: Policing the most stressful occupation: a study on Tamilnadu head constables. Int. J. Buss. Mgt. Eco. Res. **4**(5), 814–822 (2013). ISSN: 2229-6247
10. Office accommodation workspace and fit out standards, Office Accommodation Management Framework, Queensland Government, October 2012. http://www.hpw.qld.gov.au/SiteCollectionDocuments/OAMFFitoutStandards.pdf
11. Norman, R., Wells, R.: Ergonomic Interventions for Reducing Musculoskeletal Disorders: An Overview, Related Issues and Future Directions, For the Institute for Work & Health to the Royal Commission on Workers Compensation in British Columbia, pp. 1–34 (1998)
12. Prasuna, V., Neeraja, T.: Musculoskeletal symptoms due to work stress among women in packing activities of pharmaceutical industry: ergonomic interventions. Int. J. Inf. Res. Rev. **3**(11), 3032–3035 (2016)

Evaluation of Posture, Self-efficacy, Comfort and Discomfort in Guitarists While Using Auxiliary Implements for Instrument Positioning

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Abstract. The performance of classical guitar is affected by a number of factors or conditions, including auxiliary implements for guitar positioning. The aim of this study was to analyze several conditions such as posture, self-efficacy perception, comfort and discomfort in guitarists while using three different auxiliary tools for instrument positioning. The participants were nine students from the technical career in Music of the University of Guadalajara. All guitarists played fingering exercise using each one of the three implements. They were video recorded to evaluate posture. Finally, they answered a questionnaire to know their perception of self-efficacy, comfort and discomfort after using each auxiliary tool. Results shown that the implements that allow both legs supported on the floor, present greater postural advantages. However, in the particular case of self-efficacy and comfort the one that was better evaluated was the footstool.

Keywords: Occupational Ergonomics · Guitarists · Footstool · Dynarette · Ergoplay

1 Introduction

The performance of classical guitar is a complex activity and requires different elements that can change the conditions of interpretation of the instrument. Among these elements there are auxiliary implements that serve as tools to give a right position of the guitar, in order to improve the accessibility and visibility of the fretboard. Taking into consideration that these implements have a direct influence in the interaction between the music and its instrument, the conditions generated from the use of these objects can be studied from the perspective of Ergonomics.

The exposition to risk factors can affect the professional activity of musicians. A large percentage of them have problems due to incorrect posture, anti-ergonomic technique, excessive force, overuse and insufficient rest, which can lead to musculoskeletal

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injuries [1]. The guitar that 25 years ago did not figure in the statistics, has come to occupy the first place in the production of functional injuries and musculoskeletal disorders and the ages in which they appear are getting earlier [2].

Another aspect that can be affected by the use of auxiliary implements and have great importance while performing the instrument is the efficacy, and the evaluation of this factor could be made through musician's perception. In this sense, the concept of perceived self-efficacy is very useful. Human functioning is facilitated by a personal sense of self-control [3]. If people believe that they can take action to solve a problem instrumentally, it becomes more self-confident and feels more committed to this decision [4]. This variable allows to know if the conditions generated with the use of positioning implements improved the feeling of self-confidence and control over the instrument while performing.

In addition to posture and perceived efficacy, the interaction with auxiliary implements, can impact on the comfort and discomfort of the musician. Although broadly recognized as antonyms, comfort and discomfort present clear differences in their definitions, which leads us to recognize them as two variables that can be analyzed independently. There is a relation between discomfort and biomechanical and fatigue factors, whereas comfort is associated with the sense of physical well-being and aesthetics [5].

The aim of this study was to evaluate posture, self-efficacy, comfort and discomfort during the use of the three auxiliary implements for instrument positioning described previously.

2 Method

2.1 Participants

Nine students from the Department of Music of the University of Guadalajara participated in the study. They were cursing the career of music technician. Aged between 18 and 23 years old, and an experience no more than 4 years of experience in classical guitar performance. None of the participants had a history of a musculoskeletal disorder or pathological history that could affect their performance during instrument interpretation.

2.2 Stage

Tests were carried out in the facilities of the Center of Art, Architecture and Design of the University of Guadalajara, specifically in the master's degree in Ergonomics classroom. All the crystals were covered with black paper to isolate it from the outside. Illumination was artificial. All participants used an adjustable height bench with padded surface and without back support. The procedure was during the day and all video recordings on a schedule from 10:00 a.m. to 3:00 p.m.

2.3 Material and Equipment

The selection of auxiliary implements was based on the differences they present in terms of use, possibility of adjustment and materials (Table 1).

Table 1. Description of auxiliary implements for guitar positioning.

Footstool: It is an adjustable device in which the musician supports the foot and rise the thigh where the guitar rest.	 **Fig. 1 Footstool**
Dynarette: It is a cushion that has a convex curvature (above) that pretends to adapt to guitar body and another concave (below) that adapts to the thigh of the extremity where the guitarist supports the instrument.	 **Fig. 2 Dynarette**
Ergoplay: This type of tool is an adjustable device that is placed between the guitar and the thigh where the musical instrument rests. The side that rest on the guitar has a holding mechanism by suction cups, this prevents that the instrument slips or misalignment of the place that the guitarist decided initially. The side that rests on the thigh has a concave curvature.	 **Fig. 3 Ergoplay**

To explain the process to all musicians it was necessary to create an introductory video. The content of this material included specific instructions about the stages of the test, an explanation of the questionnaires to evaluate self-efficacy, comfort and discomfort, and finally, a video tutorial where the fingering exercise was played.

Three digital cameras were used to record the participants performance. Cameras were placed at the upper, back and left side of the guitarist. As mentioned before, all guitarists played with each auxiliary implement and the same instrument. The speed of exercise performance was programmed with digital metronome.

2.4 Instruments of Evaluation

The first step was to do a diagnostic analysis to find awkward and risky postures using the REBA method [6]. After completing these evaluations, and obtaining the frames where the highest postural risk was identified; the rotation and flexion of trunk, internal rotation of right humerus, abduction of the left shoulder and low back compression were measured using the 3DSSPP software, developed at the Ergonomics Center at the University of Michigan.

Perceived self-efficacy and comfort were evaluated with a 16-item questionnaire on a five-point Likert scale, eight items for each variable, with a minimum score of 8 points and a maximum of forty. The higher the score obtained in this questionnaire, the better the participants' perception for both variables.

To evaluate if participants felt discomfort while playing a body map based on the work of Corlett and Bishop [7] was applied. The evaluation included 13 body regions, based on a Likert scale of five points. With a minimum grade of 13 and a maximum of sixty-five. The higher the score reported by the participant, the greater the degree of discomfort.

2.5 Procedure

All participants were into three groups and each one of them began the tests using the three auxiliary implements randomly assigned. Before requesting the musicians to play the fingering exercise, their weight and height were determined, these data were necessary for the analysis with the 3DSSPP software. All participants were divided into three groups and each one of them began the tests using the three auxiliary implements randomly assigned. Before requesting the musicians to play the fingering exercise, their weight and height were determined, these data were necessary for the analysis with the 3DSSPP software.

After taking these anthropometric measures, participant entered to the classroom to watch an introductory video explaining the test process. They were also asked to sign an informed consent form to confirm their participation.

After finishing this part of the test, the height of the bench was adjusted to the participant's popliteth height, looking for a right angle between the leg and thigh, taking as reference the knee joint.

When guitarists were sitting on the bench, with the corresponding implement and guitar positioned, they performed four repetitions of the fingering exercise. After completing the activity, every musician answered the self-efficacy, comfort and discomfort questionnaires. Finally, they performed the exercise using every implement, and completing the questionnaires three times (one time for each implement). The metronome was programmed at a time of 80 bpm, to play two notes per pulse.

After the guitarists finished the tests, all videos were saved in the computer and later edited with a software to synchronize all shots in a single screen. After of that, one hundred frames of each video were obtained and classified according to the position of the left limb on the fretboard in the medium, high and low pitch. The representative frames were chosen according to the level of postural risk estimated through the Rapid Entire Body Assessment (REBA) and then analyzed with the 3DSSPP software.

3 Results

The average age of participants was 19.6 (±1) years. None of them reported having a musculoskeletal disorder. As part of their previous experience, seven of them used the footstool as the main auxiliary implement, one guitarist used to play with some type of adjustable implement and one guitarist didn't use any auxiliary tool.

3.1 Posture

The results reported on left shoulder abduction, internal rotation of the right humerus, flexion and axial rotation of the torso and compression of the lower back in three moments of the musical instrument (high, medium and low pitch) in the nine participants (see Tables 2, 3 and 4).

Table 2. Evaluation of posture indicators in high pitch.

Indicator	Implement	Angles (mean)	Standard deviation
Left shoulder abduction	Dynarette	22.5°	±10°
	Footstool	27.2°	±11°
	Ergoplay	19.3°	±14°
Right humerus rotation	Dynarette	90.6°	±17.1°
	Footstool	91.3°	±19°
	Ergoplay	95.2°	±14.4°
Torso flexion	Dynarette	6.4°	±3.2°
	Footstool	6.4°	±6.3°
	Ergoplay	4.3°	±2.8°
Axial rotation torso	Dynarette	9.8°	±5.2°
	Footstool	12°	±8°
	Ergoplay	11.6°	±5°
Low back compression (N)[a]	Dynarette	1488	±201
	Footstool	1528	±240
	Ergoplay	1360	±214

[a]The measure unit for low back compression were Newtons.

3.2 Perceived Self Efficacy

Table 5 shows the average ratings in the 8 items of the questionnaire for perceived self-efficacy.

3.3 Perceived Comfort

The average rating reported by the participants in the 8 items corresponding to the variable of perceived comfort. (See Table 6).

Table 3. Evaluation of posture indicators in medium pitch.

Indicator	Implement	Angles (mean)	Standard deviation
Left shoulder abduction	Dynarette	25.3º	±10º
	Footstool	29.6º	±7.4º
	Ergoplay	27.2º	±12º
Right humerus rotation	Dynarette	94.2º	±15.5º
	Footstool	96.4º	±9.4º
	Ergoplay	86.7º	±16.3º
Torso flexion	Dynarette	3.5º	±2.3º
	Footstool	6.1º	±5º
	Ergoplay	4º	±2.5º
Axial rotation torso	Dynarette	11º	±5.2º
	Footstool	10.8º	±7º
	Ergoplay	14.6º	±7º
Low back compression (N)	Dynarette	1420	±256
	Footstool	1518	±226
	Ergoplay	1390	±94

Table 4. Evaluation of posture indicators in low pitch.

Indicator	Implement	Angles (mean)	Standard deviation
Left shoulder abduction	Dynarette	40.6º	±7.2º
	Footstool	39.1º	±10.3º
	Ergoplay	39º	±8.3º
Right humerus rotation	Dynarette	94º	±13.3º
	Footstool	97.2º	±7.5º
	Ergoplay	95.3º	±18.1º
Torso flexion	Dynarette	4.6º	±4º
	Footstool	4.2º	±3.8º
	Ergoplay	5º	±4º
Right humerus rotation	Dynarette	11.7º	±7º
	Footstool	7.5º	±8.4º
	Ergoplay	13.3º	±8.3º
Low back compression (N)	Dynarette	1541	±175
	Footstool	1500	±150
	Ergoplay	1507	±188

Table 5. Average rating for the variable perceived self-efficacy.

Auxiliary implement	Mean (Points per participant)	Standard deviation
Dynarette	28/40	±9
Footstool	33/40	±6
Ergoplay	27/40	±10

Table 6. Average rating for the variable perceived comfort.

Auxiliary implement	Mean (Points per participant)	Standard deviation
Dynarette	29/40	±7
Footstool	32/40	±5
Ergoplay	26/40	±8

3.4 Perceived Discomfort

The general average of the perception of discomfort test for each auxiliary implement was obtained. (See Table 7).

Table 7. Average rating obtained in the discomfort test.

Auxiliary implement	Mean (Points per participant)	Standard deviation
Dynarette	20/65	±7
Footstool	21/65	±6
Ergoplay	21/65	±5

4 Discussion

With respect to posture, the ergoplay and dynarette contributed to a lower abduction of the left shoulder, when interpreting the fingering exercise in the highest frets. In the middle register, the dynarette was the implement with less postural deviations while using. In the lower register all auxiliary implements remained within the same range with a difference not greater than one degree between them in left shoulder abduction.

It is possible to think that these tools could be useful to positively change left shoulder abduction in the medium and high register, taking to a posture closer to the neutral while playing the instrument. However, these implements were not shown equally useful when the musician is playing the first frets of the guitar, since joint motion depends mainly on the length of the fretboard and the position that the left hand holds on it.

A positive point about the three auxiliary implements is that none of the participants had a shoulder abduction greater than 60°, which is important since biomechanically it is from that point that becomes necessary the participation of other joints to complete the movement involving a higher energy expenditure.

The internal rotation of right humerus was also used as a reference, which occurs when the forearm is placed parallel to the body of the guitar to play the strings. In the three auxiliary implements the internal humeral rotation was near to the maximum amplitude that is of 100 to 110° approximately. If guitarists keep this posture for long periods without proper support can generate health problems.

The register with the greater internal humeral rotation was the lower and there were no important differences between the auxiliary implements. It's necessary to understand that these measures were taken from the neutral position that is equal to 0 degrees; however, it is noteworthy that physiologically there is an internal rotation that is approximately 30° given by the balance provided by the rotator cuff, placing the forearm in front of the trunk naturally. What seems to influence the humeral rotation is the depth of the guitar body, since as analyzed in the frames, the guitarist needs the impeller to reach a position suitable for the strumming or the taping of the strings.

With respect to the torso flexion, during the performance in the high register, the Ergoplay had a discretely smaller deviation in comparison with the footstool and dynarette. It's possible that this lesser degree of flexion is due to a postural compensation given by other body segments, which helped to make the guitarist's back more straight. For example, in the highest register the musician at the same time that flexed the torso, also carried an axial rotation and abduction and flexion of the shoulder that helped him to reach the highest notes. Also the physical barrier that represented the instrument, helped to limit the flexion.

The results for the lower back compression shown that the Ergoplay was better than the dynarette and footstool in the high and medium registers, but no important differences were found while playing the instrument in the low register. It's important to mention that with the footstool, a compression higher than 1,500 N was reported in the three registers, which could represent a long-term risk for the guitarist, duo to hip's flexion, the pelvis is conditioned to a retroversion, which could lead to the development of lumbar kyphosis and poor distribution of body weight on the seat. With elevation of the lower left limb the weight distribution is asymmetrical. A good sitting posture is characterized by minimal muscular effort and adequate support in the seat, arms and foot support [8]; the latter condition is not generated with the footstool. It's probable that changes reported in low back compression are also related with the posture modification, to do this it is necessary certain freedom in the lower extremities that greatly aid, along with the torso flexion, to repositioning the hip and the postural load on the ischial tuberosities.

In the evaluation of self-efficacy and perceived comfort results shown that musicians had a discrete tendency to choose the footstool as the best auxiliary tool. It is possible that this preference is mainly due to the experience that musicians had with this tool. They mentioned that this device is easy to get, it is cheap and allows a greater physical contact with the instrument. This last thing is in a relation with a sense of security at while performing because there is not any artifact between the musician and guitar.

In the perceived discomfort assessment, the upper back and the buttocks/hip were the two body segments where the greatest discomfort was reported when performing; However, there were not great differences in the global discomfort rating between the auxiliary. So, in this case, none of the three guitar implements contributed to decrease the discomfort when performing the fingering exercise.

5 Conclusions

It's important to recognize that, in postural terms, the implements that allow both legs supported on the floor, present greater advantages. However, in the particular case of self-efficacy and comfort the one that was better evaluated was the footstool. This situation makes relevant the search for new options that allow to reduce the most compromising angles in the different body segments. It is important to consider the feeling of closeness and control over the instrument that seems to have a great value for musicians.

Although the ergoplay counts with an adjustment range and apparently helps to have a more straight posture, it was not reported as comfortable or reliable as the footstool. Some guitarists mentioned that the Ergoplay easily destabilize the guitar.

Taking into account the explanation in previous lines it can be concluded that auxiliary implements for guitar positioning have a positive effect at postural level, however, each one has characteristics that can be improved.

From the analysis of the performance of classical guitar will be possible to develop a proposal in which some conditions could be improved like practice habits and help the instrumentalist in countering the best auxiliary tools to keep a healthy professional practice.

References

1. Hansen, P.A., Reed, K.: Common musculoskeletal problems in the performing artist. Phys. Med. Rehabil. Clin. N. Am. **17**(4), 789–801 (2006)
2. Sánchez-Padilla, M., Bayo-Tallón, V., Esquirol-Caussa, J., Guerrero-Forteza, E., López-Iglesias, I., Salas-Gómez, D.: Incidencia de lesiones en profesionales de la guitarra clásica. Fisioterapia **35**(6), 243–251 (2013)
3. Bandura, A.: Self-efficacy: The Exercise of Control. Macmillan, New York (1997)
4. Schwarzer, R., Fuchs, R.: Self-efficacy and health behaviours. In: Predicting Health Behaviour: Research and Practice with Social Cognition Models, pp. 163–196 (1996)
5. Helander, M.G., Zhang, L.: Field studies of comfort and discomfort in sitting. Ergonomics **40** (9), 895–915 (1997)
6. Hignett, S., McAtamney, L.: Rapid entire body assessment (REBA). Appl. Ergonomics **31**(2), 201–205 (2000)
7. Corlett, E.N., Bishop, R.P.: A technique for assessing postural discomfort. Ergonomics **19**(2), 175–182 (1976)
8. Nordin, M., Frankel, V.H., Forssén, K.: Biomecánica básica del sistema musculoesquelético. McGraw-Hill. Interamericana, Madrid (2004)

Ergonomic Tools Applied in a Metallic Systems Manufacturing Industry Workstation

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Abstract. The market is increasingly competitive and due to it, industries look after their collaborators' health, aiming to increase the efficiency through better work conditions. Therefore, the application of ergonomic principles within industries have become extremely relevant, it improves the life quality at the work place, reduce injuries and increase the productivity, which is a desired factor within organizations. This study brings an ergonomic analysis made by the application of three ergonomic tools: anthropometric measures applied in the software *Antroprojeto*, OWAS method and NIOSH lifting equation in a metallic system manufacturing industry workstation where workers perform a task of manual lifting of load (metallic tiles). The application of the tools shows that methodology of work and equipment dimensions were harmful to workers. Ergonomic recommendations were suggested and promptly adopted by the company, contributing to workers health and productivity.

Keywords: Ergonomics · Anthropometry · OWAS method · NIOSH lifting equation

1 Introduction

The market is increasingly competitive and due to it, industries look after their collaborators' health, aiming to increase the efficiency by better work conditions, decreasing the incidence of musculoskeletal disorders and absenteeism from work. Along this line, ergonomics contributes to the development of knowledge and serves as a support for analyzes of products projects and productive situations.

Ergonomics comes from the Greek *ergos*, work, and *nomos*, natural law, is the science that studies people who work, the way they do it, the tools and equipment they use, the places they work in and the psychosocial aspects of the working situation [1]. So, the application of ergonomic principles within industries have become more relevant, because improve the life quality at the work place, reduce injuries and increases the productivity, which is a desired factor within organizations. For this reason, engineering teams look to acquire knowledge about methods and/or ergonomic tools to be applied as evaluation of workstation, such as Anthropometry, the OWAS method (Ovako Working Posture Analysing System) and NIOSH lifting equation (National Institute for Occupational Safety and Health).

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Anthropometry is an important branch of ergonomics that deals with body measurements such as size, shape, strength, mobility, flexibility and work capacity. As humans diversify in body dimension, anthropometric measurements become essentials when designing devices, equipment and system for users [2].

The OWAS method is one of the methods used to identify and analyze work posture to ensure comfort and safety in work. It can define the movement of all parts of the body and recommend suggestion to safer and comforter feeling during working [3].

The National Institute for Occupational Safety and Health has understood the complexities of the lifting problem and the need to develop criteria to calculate lifting loads for different situation. Thus in 1991 they have proposed a revised NIOSH lifting equation [4], whose principal product is the recommended weight limit (RWL) for load lifting performed by healthy workers for up to 8 h [5]. The criteria for establishing the weight limit are the biomechanical, physiological and psychophysical character [6].

This paper aims to apply ergonomic tools to analyze a metallic systems manufacturing industry workstation situated in Vale do Paraiba, state of São Paulo, Brazil, where workers perform a task of manual lifting of load. The main complaint of those workers is that they have back pain during the execution of their activities. With the application of the tools anthropometric measures applied in the software *Antroprojeto*, OWAS method and NIOSH lifting equation, the work conditionals were improved, decreasing the workers complaints about this activity.

2 Methodology

The study was performed inside a metallic tiles manufacturing industry in the sector of cutting and packing. The industry is situated in Vale do Paraíba, state of São Paulo, Brazil and has an industrial shed with a covered area of 7000 m^2. From this area, 210 m^2 that is located near of an exit doors are intended for the cutting and packing activity, which provides the environment a good ventilation and natural lighting. Besides that, the environment was recently restructured and has currently an adequate artificial lighting execution of the activity, as indicated in the illuminance reports produced in the shed, which were based on Brazilian standard NBR 5382. The following figure (Fig. 1) shows the factory layout with emphasis on the studied area.

The workstation studied in this paper (Fig. 2) is composed by a metallic tiles' cutting machine where metallic trestles are also used to assist the tiles' handling during the cutting process.

During normal operation, there are eight employees working in the machine, which have as tasks first the segregation of the production line's tiles and second the sending to the cutting sector. After these stages, the employees have as final task the packing and releasing of the material to the storage. The last task is performed on the metallic trestles. During the tiles cutting sector tasks execution, it was found that the manual lifting of loads is the main activity performed by workers. The medium weight lifted by each worker is 15 kg. In this sector there is task caster among the eight workers, so none of them remain in a same task during the entire work shift, which has eight hours a day, with three determined pauses: two of 15 min for breakfast and afternoon coffee, and one of 1 h for lunch.

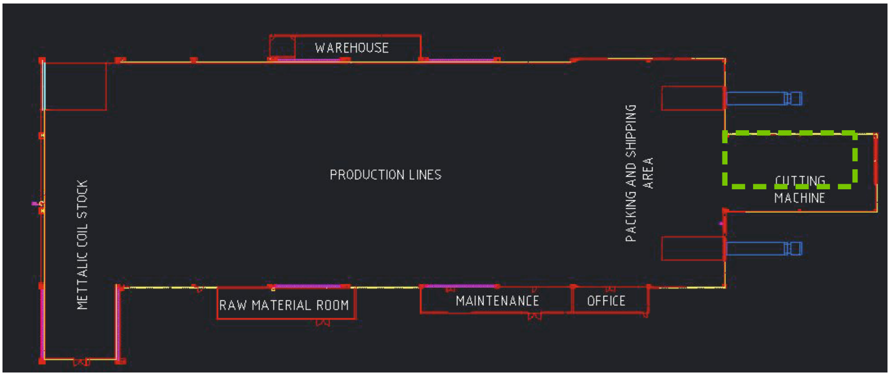

Fig. 1. Factory's layout with emphasis on the studied area

Fig. 2. Workstation studied in this paper

For workstation analysis, three ergonomic tools were used: Survey of anthropometric measurements with posterior application in the software *Antroprojeto*, the OWAS method and NIOSH lifting equation. For a better understanding, the methodology was divided in three parts, as described below:

2.1 Anthropometry

Anthropometry is defined as the science of body size's measurement [7]. The survey of anthropometric data is a relevant instrument in ergonomic studies, because through its analysis it is possible to capture the subsidies to size and evaluate machines, equipment and workstations. Through this analysis it is possible to determine whether or not there is an interaction of the anthropometric measurements of the workers in relation to the performance of their tasks. Also analyze whether these tasks are within the appropriate

Table 1. Measures of the stature of the cutting and packaging sector workers.

Employees	1	2	3	4	5	6	7	8	Arithmetic Mean
Height (m)	1,72	1,75	1,69	1,72	1,77	1,7	1,75	1,8	1,74

ergonomic criteria. [8] In order to address that need, the measure of the stature of all workers were collected and the arithmetic mean calculated, as shown in the Table 1.

The arithmetic mean value was then applied to the *Antroprojeto* software (Fig. 3). This software, which was developed by the Federal University of Juiz de Fora, uses an anthropometric mathematical model to make the estimation of all the body segments based on the value of the stature.

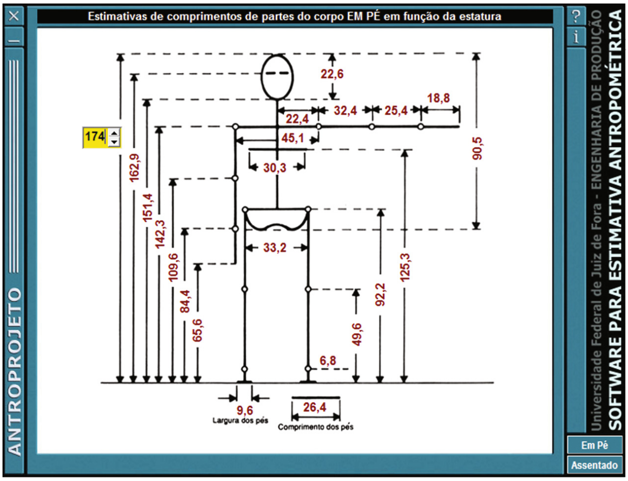

Fig. 3. *Antroprojeto* software's interface

In addition, with the help of a measuring tape, the values of the main dimensions of the equipment were raised (Fig. 4).

At the end of this stage the values of body segments' measures shown by the software were then compared to the values of the main measures of the cutting machine used in the process, which were possible to verify the ergonomic suitability of the equipment to its users.

2.2 OWAS Method

The OWAS method (Ovako Working Posture Analyzing System) provides a simple method for analyzing the postures adopted during the work. It was developed in 1977 by Finnish researchers, who worked in a steel company, through the photographic analysis of the main postures typically found in heavy industry. In the study were found 72

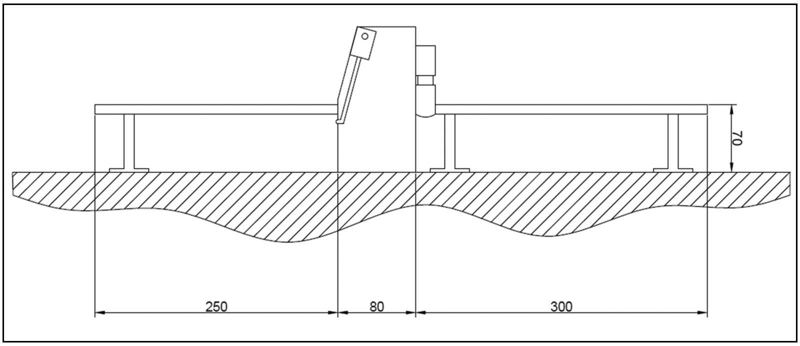

Fig. 4. Equipment overview and its main dimensions in centimeters

typical postures, which result from different combinations of the positions of the back, arms and legs (Fig. 5) [9]. In addition, the loads used are also taken into account [6].

From the analysis of the variables back, legs, arm and load, the postures can be classified into one of the following categories [9]:

- Class 1 - normal posture, which does not require care, except in exceptional cases;
- Class 2 - posture that should be checked during the next routine review of working methods;

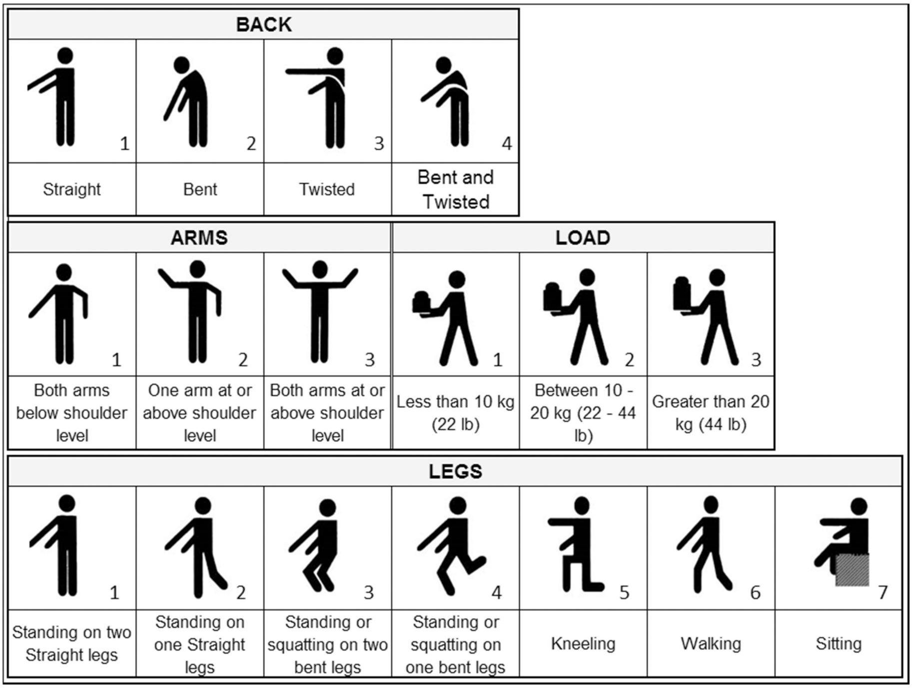

Fig. 5. OWAS method postures chart. Adapted from [9].

Table 2. Postures classification by the combination of variables. Adapted from [9].

Back	Arms	1			2			3			4			5			6			7			Legs
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	Loads
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	2	
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	2	2	2	2	3	3	
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4	
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4	
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1	
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1	
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1	
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4	
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4	

- Class 3 - posture should be checked in the short term;
- Class 4 - posture that should be checked immediately;

The classes depend on the combination of the variables back, arm, legs and load [9], as shown in the Table 2. They can also depend on the duration of the postures. The first approach was chosen by the researchers to be applied in the study, because there was not time available to perform the second approach.

Based on the OWAS method, the postures adopted by the workers during the load (tiles) lifting activity were observed in a spot check and described in detail by the researchers, since authorization was obtained for the study, except for photographing or filming the workers. The following figure (Fig. 6) illustrates the postures most adopted by the workers during the execution of the tasks in the cutting tiles workstation.

Each of these postures was classified individually through the combination of the variables back, arm, legs and load, which allowed the identification of their respective classes. Finally, actions were suggested to eliminate the adoption of positions framed between classes 2 and 4 in the execution of this activity.

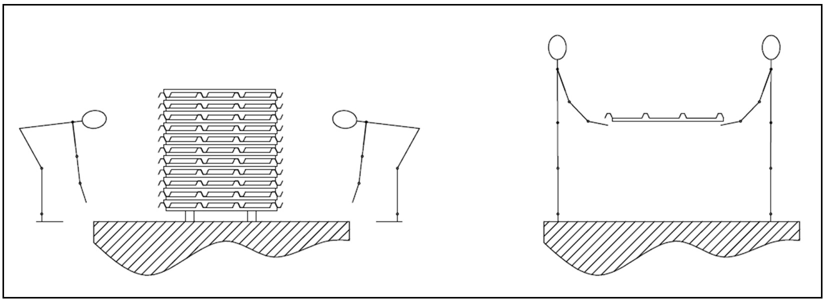

Fig. 6. Main positions adopted during the task of tiles lifting

2.3 NIOSH Lifting Equation

The most various production sectors of the industry continue concerning with the manual lifting of loads carried out by the employees. Actually, there is a large number of occurrences of low back pain resulting from the incorrect accomplishment of this activity [11]. In 1981, the problem was recognized by the National Institute for Occupational Safety and Health (NIOSH), which published the Work Practices Guide for Manual Lifting. Among other things, the document presented a lifting equation to calculate a recommended weight for specified two-handed, symmetrical lifting tasks. The same equation was subsequently revised and published in 1991 by NIOSH staff [5]. Its main goal is to prevent or reduce the occurrence of low back pain in workers performing the load lifting during work [10].

The main product of the revised NIOSH lifting equation is the RWL (recommended weight limit), which is defined by the following equation:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM \tag{1}$$

The recommended weight limit (RWL) for lifting is a recommended load that healthy workers can perform for up to 8 h. In ideal situations, the maximum value of load is 23 kg, related in the equation as (LC). The others multipliers are: Horizontal multiplier (HM), vertical multiplier (VM), distance multiplier (DM), asymmetric multiplier (AM), frequency multiplier (FM) and coupling multiplier (CM). Each multiplier has a coefficient, which is established in function of the values found in the specific task [5].

Another term related to this equation is the LI (lifting index), is defined by the following equation. The LI estimates the level of physical stress associated with a particular manual lifting task by the relationship of the load lifted weight and the recommended weight [5].

$$LI = L/RWL \tag{2}$$

Aiming to analyze the relationship of the weight lifted by the workers with the back pain reported by them, both equations were used according to the Applications Manual for the Revised NIOSH Lifting Equation, 1994. The necessary measurements were raised with the use of a measuring tape. Only the static posture adopted during the activity was analyzed, since the equation should not be applied in activities involving movement of loads [5].

3 Results and Discussion

3.1 Anthropometric Analysis

At the workstation intended for tiles cutting it was identified that there is a suitable area for the movement of the workers around the equipment, because there is no obstacle. In addition, it was verified that the machine mats and the trestles allowed the correct positioning of the workers' feet during the load's lifting and handling activity. It also allowed the worker to adopt the upright posture during the activity execution.

For heavy work, the ideal working surface height should be up to 30 cm below the elbow height [9]. Thus, the equipment was considered inadequate to perform the activity, since the value of the difference found between elbow height and equipment height was 72.3 cm. For this reason, it was suggested an adequacy in this parameter, which was promptly done by the company. Supports were placed on the feet of the equipment and new trestles were manufactured, both with the height of 115 cm. Thus, the difference in values was adequate, as indicated by the literature, adapting the workstation to the task.

3.2 OWAS Method

The two main postures adopted during load lifting, which were already shown (Fig. 6), were analyzed using by means of the OWAS method.

The classifications used the factors of the Fig. 5. The following factors were used in the classification of the inclined posture adopted for lifting the tile: Back as 2, arms as 1, legs as 3 and load as 2. The class found was: 3 - posture should be checked in the short term.

The following factors were used in the classification of the upright posture: back as 1, arms as 1, legs as 1 and load as 2. The class found was: 1 - normal posture, which does not require care, except in exceptional cases.

By the analysis of the obtained results, the adoption of the inclined posture was considered harmful to the workers, since it is in the class 3.

Following the class' orientation, the posture was analyzed and a solution was raised and adopted. Instead of making the workers to remove the tile from the floor, the pile of tiles was divided in two parts and then placed on trestles, which decreased the workers' body inclination during the activity (Fig. 7).

The new posture was then analyzed by means of the OWAS method. The parameters used were: back as 1, arms as 1, legs as 1 and load as 2. The class found was: 1 - normal posture, which does not require care, except in exceptional cases.

The obtained result proves that the posture adopted for the execution of the activity was improved after the application of the OWAS method.

3.3 NIOSH Lifting Equation

Through the application of NIOSH lifting equation, the recommended weight limit (RWL) found was 11,974 kg and the lifting index (LI) was 1,253.

The results show that the weight lifted by the workers (15 kg) was above the ideal weight (11,974 kg). In order to correct this situation, a suggestion was made. A reduction in the spacing between the workers while performing the tiles' lifting was suggested in order to achieve a better distribution of the weight of the material.

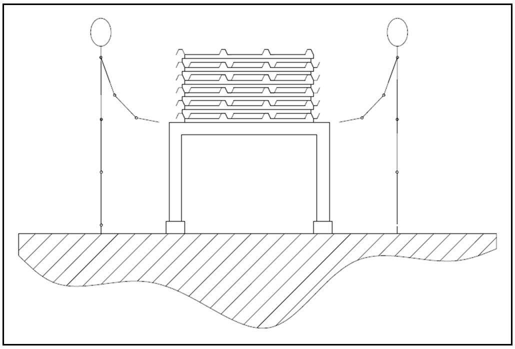

Fig. 7. New method for tiles lifting

4 Conclusion

The application of ergonomic tools anthropometry through the software Antroprojeto, OWAS method and NIOSH lifting equation allowed an adequate evaluation of the workstation. The results of the application of such tools show that the work methodology adopted and the dimensions of the equipment used in this workstation were harmful to the workers. This scenario evidenced the need to adopt corrective actions in order to improve working conditions, which were suggested by the researchers and promptly implemented by the company. The actions implemented proved to be effective in solving the problem faced by the workers, since no complaints about back pain were reported during the execution of the activity after the improvement implementation, proving the efficiency of the use of the tools adopted in the adequacy of workstations.

It is hoped that this research encourage engineering teams to seek to acquire knowledge about the operation of ergonomic tools, so that they can apply them in the design of equipment and layouts of production systems.

Despite the significant technological advances in the area, the equipment used in the metal tile manufacturing industry shows deficiencies in its suitability to the end user, evidencing the need for new studies in this area.

References

1. Pheasant, S., Haslegrave, C.M.: BODYSPACE: anthropometry, ergonomics and the design of work. 6000 Broken Sound Parkway NW, Suite 300, vol. 3, pp. 1–4. Taylor & Francis Group (2005)
2. Salvendy, G.: Handbook of Human Factors and Ergonomics, vol. 4, pp. 168–169. John Wiley & Sons, Hoboken (2012)
3. Wahudi, M.A., Dania, W.A.P., Silalahi, L.R.: Work posture analysis of manual material handling using OWAS method. In: ICoA International Conference on Agro-Industry, pp. 195–199. ICoA Press, Indonesia (2014)

4. Luximon, A.: Dynamic footwear fit model similar to NIOSH lifting equation. In: 6th AHFE International Conference on Applied Human Factors and Ergonomics, pp. 3734–3737. AHFE Press, Las Vegas (2015)
5. Waters, T.R., Anderson, V.P, Garg, A.: Application manual for the revised NIOSH lifiting equation. In: NIOSH National Institute for occupational Safety and Health Division of Biomedical and Behavioral Science, Cincinnati, Ohio (1994)
6. Másculo, F., et al.: Ergonomics: Adequate and Efficient Work, vol. 1, pp. 284–299. Abepro. Elsevier, Rio de Janeiro (2011)
7. Churchill, E., et al.: Anthropometric source book. Volume 1: Anthropometry for designers. In: NASA 1978, vol. 1, pp. IV. NASA, Houston (1978)
8. Silva, K.R., et al.: Anthorpometric evaluation of workers from the UBÁ furniture industrial pole, minas gerais, vol. 30, pp. 613–618. Revista Árvore, Viçosa-MG (2006)
9. Iida, I.: Ergomonic: Design and Production. In: Blucher 2005, vol. 2, 97–159, São Paulo (2005)
10. Waters, T.R., et al.: Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics **36**(7), 749–776 (1993)
11. Gonçalves, M., Pereira, M.P.: Manual survey of load of short repetitive duration with and I the use of pelvic belt: effect on emg activity normalized by different indicators **11**(2), pp. 152–159 (2009)

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