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RAISING WORKPLACE SUSTAINABILITY WITH ERGONOMICS ASSESSMENT METHODS

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Abstract: *It is not enough that companies invest in development and focus on profit only. Social sustainability is also becoming increasingly important. This article concretizes the ergonomics concept through the Sustainability Index indicators proposed in the previous study. The ergoIA software was used in a toolmaking company to study how ergonomics assessment results can be used indirectly to determine the value of indicators in the Sustainability Index used. The research finds that direct use of the OWAS and REBA ergonomics assessment methods results is not possible, but it offers the view in the part of the Sustainability Index. Ergonomics assessments affect some social indicators, especially health and safety, economic indicators such as operational labor costs and environmental indicators. The study can encourage companies to become aware that job ergonomics affects companies' indicators.*

Key words: *Ergonomic assessments; Ergonomics risk; ErgoIA; Sustainability Index; Tooling industry*

1. PROBLEM DESCRIPTION

Sustainability is becoming an increasingly important topic. There are three interrelated dimensions of sustainability - environmental, economic, and social [1, 2, 3]. Above all, companies are aware of and strive to achieve environmental sustainability, as several legal restrictions have been introduced in the field of the environment, which forced companies to adhere to and consequently invest in sustainability [2]. Environmental sustainability is, according to Goodland [3]: "a set of constraints on the four major activities regulating the scale of the human economic subsystems: the use of renewable and nonrenewable resources on the source side, and pollution and waste assimilation on the sink side". The second dimension of sustainability, in which companies invest their efforts, economic sustainability is [4]: "an economically sustainable company guarantees sufficient cashflow to ensure liquidity at any time, while producing a persistent above-average return to its shareholders." Minor investments and efforts in the companies are put into social sustainability [5]. Social sustainability is about how to manage business positive and negative impacts on people [6]. When companies want to achieve some milestones for sustainability, this requires a comprehensive approach which encompasses all dimensions and elements of sustainability [1].

We can find some evidence that ergonomics should be an essential part of sustainability in the scientific literature. According to [7], ergonomists are those who can promote safety and productivity in the workplace. That ergonomics affects the performance of a company and, therefore, should not be ignored is also evidenced by definition from International Ergonomics Association [8]: "Ergonomics (or human factors) is the scientific discipline concerned with the interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimise human well being and overall system performance." A literature review on REBA method applications [9] indicates that 50% of all studies included in the literature review may be an indicator of sustainable processes.

In [10], the ergonomics assessment was linked with the social sustainability framework. This study first covers the gap between ergonomics assessment methods and sustainability. It also revealed that ergonomics assessment methods are not suitable for addressing environmental concerns.

This article is based on the Sustainability Index proposed by [1], where all three pillars of sustainability are included in the process industry index calculation. Although authors focus only on the social dimension, they describe also other two dimensions. Their map of sustainability indicators is a valuable input for our work where we assume that ergonomics arrangement of workplaces affects all three dimensions of sustainability.

We chose a workplace in the tooling industry as an experimental environment to confirm our assumption. Chapter two explains the selected industry and the reason for the choice in more detail. Chapter three describes the methodology used to confirm the hypothesis. The fourth chapter describes the tools and methods for ergonomic assessment that have been used. In the fifth chapter, the results of ergonomics analysis for the workplace and the connection of proposed solutions and the previously mentioned Social Index are presented. A short description of further research and conclusions follow.

2. APPLICATION FIELD

The tooling industry is complex and highly innovative on one side and a very labour-intensive industrial sector on the other side. Every assembly part produced is unique, and due to that, the functionality and quality of tools are dependent on the craftsmanship of the toolmaker [11]. Produced tools' quality affects the quality of products in the customer's industry [12].

In Europe, there are more than 7,000 companies in the tooling industry sector, representing an average annual turnover of 13 billion USD [13].

The specificity of the tooling industry is that each product they make is unique and tailored to a specific customer. Tooling industry products are characterized by considerable variability of specifications and technical requirements, making it impossible to automate production fully.

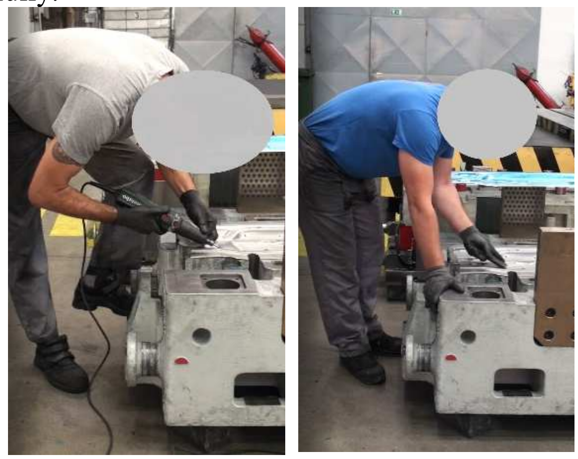

Fig. 1. Analysed workplace.

The manual labour of employees in this specific industry will thus always be part of the production process. Manual, repetitive work is a part of the production and assembly area. Described gives weight to the correctness of this specific work environment selection for the case study.

This article focuses on the manufacturing process in the tooling industry, or more precisely, in the workplace in the production hall, which includes the final corrections of the produced tools for automobile industry. Before ending the production process, produced tools are soaked in blue colour. With the shade of the colour, the accuracy of tools dimensions is determined. Based on this test, a certain amount of material is removed to get dimensions within the required tolerance field. Needed corrections could be done manually (Figure 1 left) or with the electric tool (Figure 1 right). The choice of which tool the worker will use to make corrections is entirely up to the workers' experience and his assessment of which tool will be more accurate.

As shown in Figure 1, the postures of the workers' bodies are approximately the same regardless of the tool chosen. The main difference is in the movements of worker's hands.

3. RESEARCH STAGES

The research process consisted of six steps presented in Figure 2.

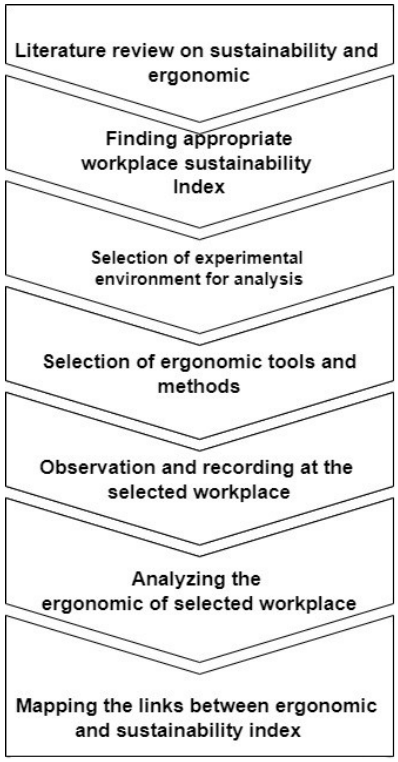

Fig. 2. Research steps.

The first step was to conduct a literature review on sustainability and ergonomics. The main goal was to find a workplace Sustainability Index. Based on review, it was decided to use the index for process industry defined by [1].

In step 2, the experimental environment was chosen. For analysis, the workplace in the tooling industry was selected. The choice was made because of specifics in the tooling industry, described in chapter 2, and because the selected company has never systematically studied ergonomics and its effects on company sustainability and business in general. Nevertheless, all workplaces in the company are regulated according to set safety standards. The company have adopted a code of ethics.

In step 3 ergonomic methods and tool has been selected. We decided on several methods of assessing ergonomics. Due to poor accuracy and lack of time for the evaluation pen-and-paper approach, we first choose the appropriate advanced software tool for ergonomic assessment. Given the advantages and accuracy offered by the latter, we found a suitable program (ErgoIA) that performs the analysis automatically. Selected software tool ErgoIA enables ergonomic assessment with OWAS and REBA methods. According to the literature review, both methods proved to be the most appropriate for the selected experimental environment.

After all decisions about experimenting, the work in the selected workplace in the tooling industry was recorded (step 4). The filming was performed with smartphones, and all the instructions for the selected tool [14] were followed. Employees in the selected jobs were briefed on the course and purpose of the experiment. They were also informed about the purpose of data collection and signed a consent to use the collected material.

The recorded material was analysed (step 5) with the help of ErgoIA to evaluate ergonomic risks in the selected workplace. As described before, two established ergonomic methods were used for ergonomic assessment.

The last step was to use the results from ErgoIA and map the links between ergonomics and the Sustainability Index.

4. METHODS USED

As beforementioned, REBA and OWAS methods were used for the ergonomic assessment with the help of ErgoIA. Used software tool and both methods are more precisely described below.

4.1 Motion Analysis Software ErgoIA

For the ergonomic assessment, the software ErgoIA was used. ErgoIA uses Artificial Intelligence (AI) to perform an ergonomic risk assessment. Besides AI, the software uses Computer Vision to evaluate the process and employees' body movements [15].

The advantage of the selected software is that it does not require special hardware to record videos, but the recordings taken with a mobile phone, tablet or camera also can be used [15].

Software processes the video imported and interprets workers' body movements. During the process, it assigns ergonomic risks that one can observe. The software enables counting of body movements, analysis of movement risks and generation of a document with analysis according to OWAS, REBA and repetition standards.

The decision-maker receives the full results after the end of the processing and can take action based on the results [15].

For risk levels, ErgoIA provides a graphical representation that marks risk levels by colour:

- Green - inappreciable risk,
- Grey - low risk,
- Yellow - medium risk,
- Orange - high risk,
- Red - very high risk.

4.2 REBA (Rapid Entire Body Assessment Method)

Among different methods for ergonomic assessment, REBA is generalized and used in many sectors [9]. REBA method was developed in 2000 by Sue Hignett and Lynn McAtamney [16], who, with the help of ergonomists, nurses and physiotherapists, analysed 600 working postures. REBA is a systematic process that enables analysis of the whole upper limbs (arm, forearm, wrist), torso, neck, legs, and knees. It also distinguishes between different types of grips and muscle activity. Body parts are divided into group A (arm and wrist) and group B (neck, trunk, and legs). REBA enables evaluation with scores on a scale from 1 to 15, grouped into five levels of risk from negligible risk when no action is required to very high risk when the change must be implemented [7, 15].

REBA requires obtaining a permit from the worker performing the job that we want to assess ergonomically. It is recommended that the observer interview the worker to explain the course of observation and to get some information and a deeper understanding of the workplace [17]. Observation of the worker could be done with direct observation, video recording or taking photographs [9]. REBA is relatively simple to use and is cost-effective. Considering two groups of body parts, ergonomic aspects are identified from the individual assessment [9].

The limitations of REBA are [7, 16]:

- Just one side of the body (left or right) could be observed at once, so for one person doing one task, more observations must be performed,
- There is a risk that REBA will overestimate the risk for Musculoskeletal Disorders (MSD) – the overestimation is expected in of 45% cases,
- It measures just the effort intensity and does not consider the duration and frequency of exposure,
- It does not consider all risk factors such as awkward posture, load/force, coupling, repetitive and static activities.

4.3 OWAS (Ovako Working Posture Analysing System)

The OWAS method was first used in the steel industry – production of steel bars and profiles [19]. It is a method for the evaluation of working postures and ergonomic analysis. Working postures are different positioning of the body, arms, legs, head and back [12].

Unlike the REBA, OWAS allows identifying the time spent in a specific posture and the frequency of a specific posture [20]. Together there are 17 different body postures and categories for analysis, divided into four categories: arms (3 postures), legs (7 postures), back (3 postures), and weight of the load handled (3 categories) [20]. Together there are 252 possible combinations [21]. Each posture has its unique four-digit code. Each code belongs to one of the four risk categories. The first category means no harmful effect on the musculoskeletal system. In this case, the workplace does not need any attention to improve the ergonomics of the workplace. The last one means a very harmful effect, and in this case, the workplace needs immediate consideration.

Advantages of using the OWAS methods are [12,19]:

- Its simplicity,
- Allows good intra- and inter-observer repeatability.

Limitations, on the other hand, are [20]:

- It does not consider repetition and duration of the sequential postures,
- It does not consider some parts of the body such as the neck, elbows and wrists.

5. RESULTS

Two work tasks were analysed for correction of tools surfaces: correction with the manual tool and correction with the electric tool. Correction with the manual tool was selected for REBA assessment, while correction with the electrical tool was selected for OWAS assessment. However, there are limited differences between the two tasks (tasks are more precisely described in chapter 2). A slight difference being observed in the position of hands while handling the tool. For both REBA and OWAS analysis, the video recordings were split into nine (9) frames each. This provided sufficient detail to identify all relevant postures and related risks.

5.1 REBA analysis

Analysis of REBA assessment of corrections with the manual tool revealed that the task involves a high ergonomic risk (Figure 3) for a majority of the postures adopted by the worker. Also, the high risk is strongly linked with repetitive hand movements.

Figure 4 indicates the primary source of risks in the Score A category. Standard REBA procedure and Score A and B are described in chapter 4.2 and in [17]. Score A was high (6 or 7) in 90% of the analysed frames. The worker's back is the most affected by postural strains, which is confirmed by the assessment results of each body region (Figure 5a and Figure 5b). The leading cause of high postural strain in the back area is the inadequate height of the working surface compared to the workers' height. Moreover, Score B was at the medium level (4 and 5) in 40% of the postures due to the unnatural position of the wrists (twisting).

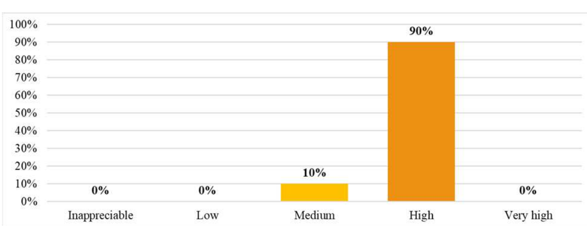

Fig. 3a. Distribution of general REBA scores.

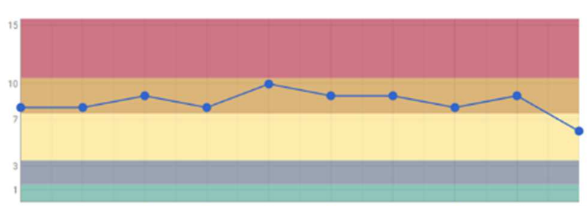

Fig. 3b. Distribution of general REBA scores.

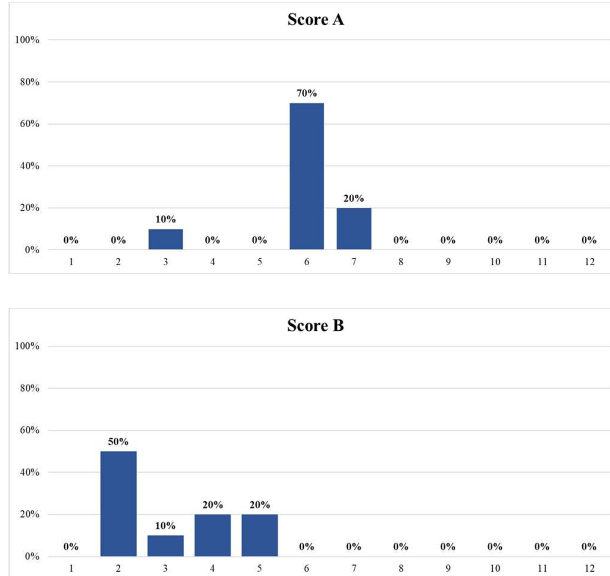

Fig. 4. Distribution of partial REBA scores.

Fig. 5a. Distribution of REBA scores by body region (arms, forearms, wrists).

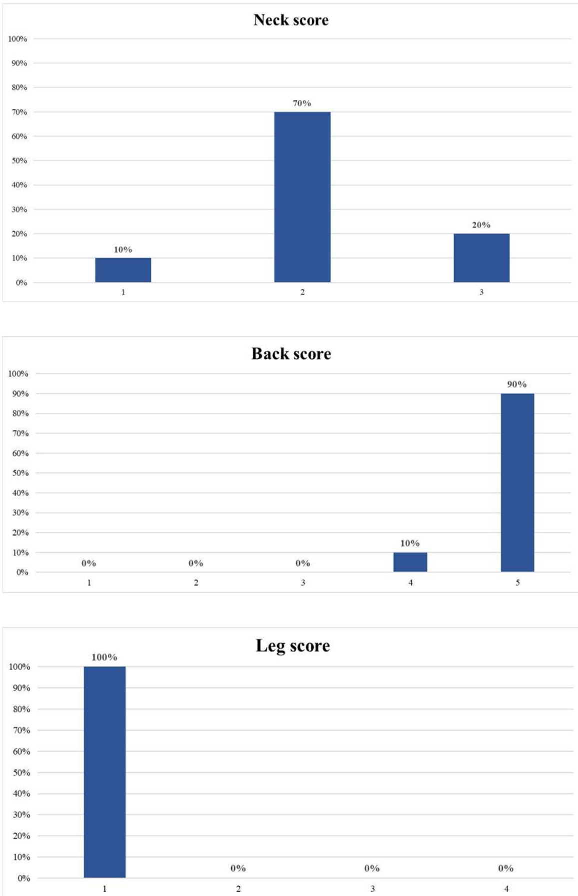

Fig. 5b. Distribution of REBA scores by body region (neck, back, leg)

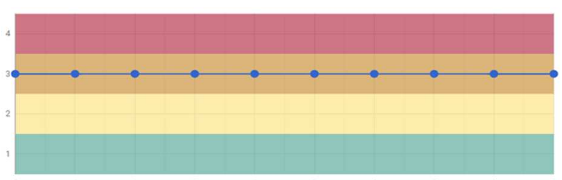

Fig. 6. Distribution of general OWAS scores.

5.2 OWAS analysis

Figure 6 shows the OWAS assessment of corrections with the electric tool. It indicates high ergonomic risk for the whole task duration, such as the REBA assessment for corrections with the manual tool.

OWAS assessment revealed that the whole analysed time was scored as high risk (Figure 6). A more detailed histogram of postures in Figure 7 shows that the most prominent postures during the task are bent back, both arms below the shoulder, and on bent knee.

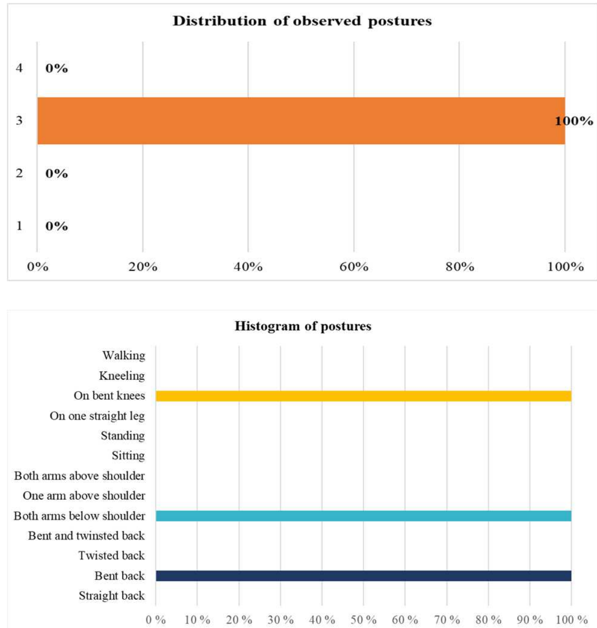

Fig. 7. Distribution and histogram of postures.

5.3 Proposed solutions

Considering the results of the assessments above, a series of identified problems and suggested improvements are offered in Table 1.

Altogether there were identified six different problems of the analysed workplace. Identified problems relate to the high of working surface, repetitive movements, and painful working postures, which are characteristics of corrections with both tools (manual and electric). The other three problems are related only to the process with the electric tool: wrist twisting, hand vibrations and high noise level.

For identified problems, ten solutions were proposed. Most of the solutions (7) are related to technical and organizational solutions. Two are related to risk reduction at the worker level and one with risk reduction at the source.

5.4 Links between the use of ergonomic methods and the social sustainability in the workplace

The Sustainability Index for the workplace proposed by Husgafvel et al. [1] consists of five indexes (Figure 8): plant information, environmental indicators, social indicators, economic indicators, and the last cross effect of all the beforementioned.

Table 1

Proposed corrective measures for correction with manual and electric tools

Identified problem	Proposed solution	Type of solution
Working surface (height too low)	Installation of a hydraulic lifting platoform that allow the worker to adjust the heght at the working surface	Risk reduction at the source
	Exoskeleton that would support torso while bending and wourld also allow sit-sand working	Technical and organizational measures, optimization
Repetitive movements	Acquisition of more perfomant tools with improved surface adn finishing results obtained with a less movements	Technical and organizational measures, optimization
	Training workers to improve efficiency and reduce the execution time	Risk reduction at the worker level
Work in tiring / painfull position	Job rotation to reduce exposure to postural strains	Technical and organizational measures, optimization
	Introduction of micro-breaks to reduce the time of exposure to such working postures	Technical and organizational measures, optimization
	Training workers to do stretching and muscle relaxation exercises during breaks and to raise awareness of implications of ergonomics risks	Risk reduction at the worker level
Wrist twisting while operating electric tool	Workplace re-organziation to allow the worker to move around the working surface, thus avoiding the unnatural working postures	Technical and organizational measures, optimization
Hand vibrations while operating an electric tool	Installation of vibration damper on the tool	Technical and organizational measures, optimization
High noise level	Measurements of noise and implementation of noise reduction measures	Technical and organizational measures, optimization

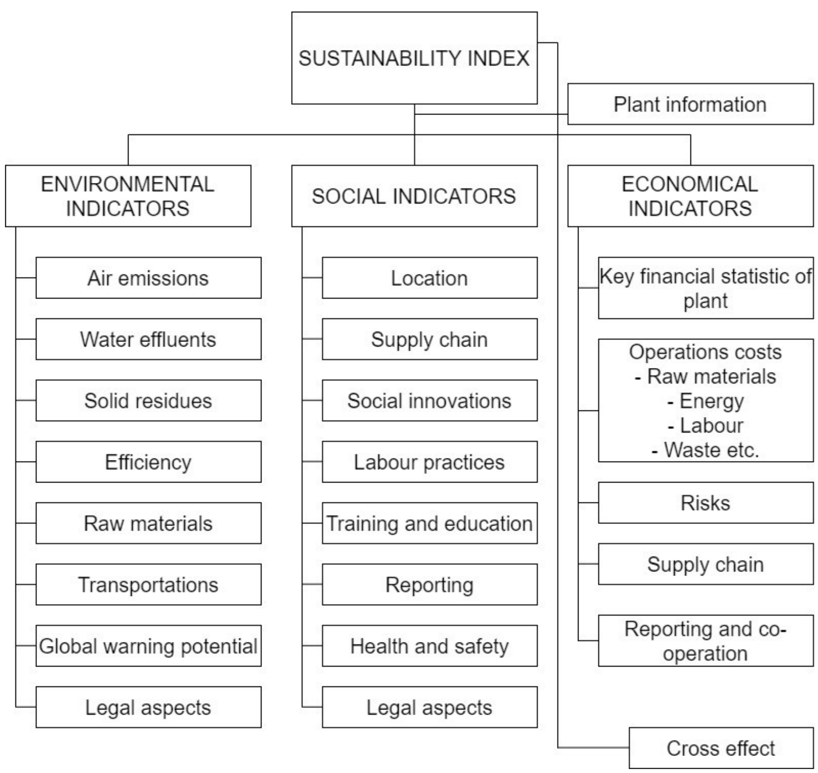

Fig. 8. The social Sustainability Index proposed by Husgafvel et al. [1].

Table 2

Links between types of solutions and social indicators from the Sustainability Index, proposed by Husgafvel et al. [1].

Social indicators from the Sustainability Index	Technical solution	Organizational solution	Risk reduction at the source of its generation	Risk reduction at the worker level
Location				
Supply chain				
Social innovation	• Performant tools • Noise reducation measures	• Micro-breaks		
Labour practices		• Job rotation • Micro-breaks		
Training and education		• Trainings to improve efficiency and reduce time		
Reporting				
Health and safety	• Performant tools • Workplace re-organziation, re-design • Installation of a vibration damper • Noise reduction measures	• Trainings to improve efficiency and reduce time • Job rotation • Micro-breaks	• Hydraulic lifting of working platform • Use of exoskeleton	• Exercises, raise awareness on implications of ergomnomic risks
Lega aspects				

Table 3

Links between types of solutions and economic indicators from the Sustainability Index proposed by Husgafvel et al. [1]

Social indicators from the Sustainability Index		Technical solution	Organizational solution	Risk reduction at the source of its generation
Key financial statistics of plant				
Operational costs	**Raw materials**	• Performant tools		
	Energy	• Performant tools	• Trainings to improve efficiency and reduce time	
	Labour	• Workplace re-organziation, re-design • Installation of a vibration damper • Noise reduction measures	• Trainings to improve efficiency and reduce time • Job rotation • Micro-breaks	• Exercises, raise awareness on implications of ergomnomic risks
	Waste	• Performant tools		
Risks				
Supply chain				
Reporting and co-operation				

Table 4

Links between types of solutions and environmental indicators from the Sustainability Index proposed by Husgafvel et al. [1]

Social **indicators from the Sustainability Index**	**Technical solution**	**Organizational solution**
Air emission		
Water effluents		
Solidresidues		
Efficiency	• Performant tools	• Trainings to improve efficiency and reduce time • Micro-breaks
Raw materials	• Performant tools	
Transportation		
Global worming potential		
Legal aspects		

In the study performed by Husgafvel et al. [1], presented indicators were used to implement social sustainability performance indicators in the process industry at the plant level.

In this article, a comprehensive selection of indicators for the Sustainability Index is used to assess the sustainability maturity in the workplace with the assumption that at least one ergonomic method could be determined for each sub-indicator.

The ergonomic methods (especially performed with some software tools) give us a deep insight into the ergonomic assessment of the workplaces. In our case, the ergonomic assessment was done based on the OWAS and RULA. Results that define risky body postures and the severity of risk for specific workplace activity cannot be used directly to calculate the Sustainability Index. Links between the use of ergonomics methods and the workplace Sustainability Index can be seen more realistically by implementing proposed solutions due to recognized risks. Practical use of two ergonomics methods in the workplace in toolmaking industry revealed risks and proposed several solutions described in 5.3. Table 2 presents intersections between possible solutions based on identified risks using OWAS and REBA methods and social sub-indicators to link the workplace Sustainability Index and the ergonomics concepts.

Social indicators are divided into eight sub-indicators [1]. Five of them are closely related to the ergonomics assessment and proposed solutions. As social innovations represent the innovations in social matters and social investments in the company, two technological solutions (performant tools and noise reduction measures) and one organisational could be placed into this category (introduction of micro-breaks). Job rotation and micro-breaks (as organizational solutions) could be placed into labour practices monitoring as this sub-indicator measures working time and overtime. Training to improve efficiency and reduce the time of execution (organizational solutions) affects the training and education sub-indicator as this indicator focuses on training, education, and competence development. Most matches between identified problems and indicators are connected with health and safety. Matches are represented with four technical solutions, three organizational solutions, two risk reductions at the worker level, and two risk reductions at the source effects on the sustainable index.

Table 3 presents intersections between possible solutions based on identified risks using OWAS and REBA methods and economical sub-indicators to link Sustainability Index in the workplace and the ergonomics concepts.

Identified solutions affect one economic sub-indicator – operational costs. The use of more powerfull tools with improved surface finishing results can reduce raw material and energy consumption, and produce less waste. With the use of more advanced tools, there is a smaller chance of making mistakes on the finished product. Training workers to improve efficiency and reduce the time of process execution affects energy and labour consumption since the work process is completed faster, which saves energy that is otherwise used for work (especially when using electric tools) and increases the efficiency of workers. Workspace re-organization affects the labour, thus avoiding the unnatural position of wrists. Uncomfortable positions of the wrists (as well as other parts of the body) cause pain, which can lead to long-term or frequent sick leave of workers. In addition to the above, the following solutions may affect employee costs: installation of the vibration damper, noise reduction measures and micro-breaks since all of them reduce the possibility of the onset of pain or illness. With the job rotation, it can also be achieved that an individual worker is burdened for a shorter period and has smaller possibilities to get body pain. Implementing the micro-breaks between the process and performing exercises for relaxation allow the worker to relax to relieve his body. Such small measures can have a significant impact on reducing the incidence of the disease.

Table 4 presents intersections between possible solutions based on identified risks using OWAS and REBA methods and environmental sub-indicators to link the Sustainability Index in the workplace and the ergonomics concepts. There are minor links between solutions and environmental indicators. Implementing performant tools (as a technical solution) causes and increases efficiency and reduces the use of raw materials.

In addition, by training workers to improve efficiency and reduce execution time and introducing of micro-breaks workers are more efficient at work.

6. CONCLUSION

This article presents the ergonomic assessment of a carefully selected workplace, without the potential for full automatisation in the tooling industry. The assessment was done with the help of novel software ErgoIA. We needed a workplace ergonomics assesment to connect improvement solutions with the Sustainability Index. The chosen workplace showed potential for ergonomics improvements since the REBA assessment indicates 90 % and OWAS 100 % of the time in which high-risk body movements are performed. Ten solutions were identified to improve the ergonomics of the selected workplace.

The literature review indicates that improving ergonomics coincides with the sustainability planning in the companies. Nevertheless, a research gap is observed in ergonomics' impact on sustainability, partially bridged by [10], which proves a correlation between social sustainability and ergonomics. This article is novel since it investigates the correlation between dimensions of sustainability and ergonomics. With practical examples, it is confirmed that arrangements of workplaces affect all dimensions of sustainability. The links between proposed solutions to improve the ergonomics of the selected workplace and four social, two environmental and one economic sub-indicators by [1] are explained.

Further research will be the way to fill the gap in how the operations of changed workplace system based on ergonomic assessment could be described with indicators and directly used to calculate the Sustainability Index. In this study, we introduce the links between types of proposed solutions and indicators of Sustainability Index. However, we are not able to quantify the impact the installed solutions based on the ergonomics assessment have on the change of specific index value.

So far, we are only able to say on which (sub-)indicators improved ergonomics of workplaces is influencing. Explained causal links between the type of solution and (sub-)indicators of the Sustainability Index are only the first step, which will be followed by determining the method of calculating the impact of ergonomics improvements and their contribution to the companies' Sustainability Index.

Furthermore, there have been considered for future research the context of different university-industry collaborations due to the mutual advantages for education and research activities, and thus, universities could providevaluable consulting activites in the filed of ergonomics and occupational health and safety [22]. Despite the difficulties of the post pandemic period, ther have been an important attention given to health and safety problems to assure production continuity in all companies and this has been an excellent context for ergonomics to demonstrate its utility and effectiveness. In addition, the ergonomics optimizations are related to the improvement of the workplace wellbeing and could offer new innovative methods of action for human resources manager (see the increase of the labour productivity demonstrated in [23]). From the practical perspective, this implications are contributed to the human/intellectual capital management [24-26], having echoes on mentaining high levels of competiveness [27], simultaneously with the managers concerned on greening organizational processes [28].

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Creşterea sustenabilității la locul de muncă prin metode de evaluare ergonomică

Nu este suficient ca întreprinderile să investească în dezvoltare și să se concentreze doar pe profit. Sustenabilitatea socială devine și ea din ce în ce mai importantă. Acest articol concretizează conceptul de ergonomie prin indicatorii Indicelui de Sustenabilitate propuși într-un studiu anterior. Software-ul ergoIA a fost folosit într-o companie producătoare de unelte, pentru a studia modul în care rezultatele pot fi utilizate indirect pentru a determina dimensiunea sau valoarea indicatorilor din Indicele de Sustenabilitate utilizat. Cercetarea constată că utilizarea directă a rezultatelor OWAS și REBA nu este posibilă, dar oferă perspectiva parțială asupra Indexului de Sustenabilitate. Ergonomia evaluează efectul asupra unor indicatori sociali, în special asupra sănătății și siguranței, indicatorilor economici, cum ar fi costurile operaționale cu forța de muncă și indicatorii de mediu. Studiul poate crește gradul de conștientizare asupra faptului că ergonomia locului de muncă afectează indicatorii de performanță și sustenabilitate ai companiilor.

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