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ERGONOMIC INTERVENTIONS IN SHAPING THE SUSTAINABLE DEVELOPMENT OF ORGANIZATIONS

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Purpose: The aim of this article is to predict the impact of selected ergonomic interventions (EIs) on the variables of sustainable development of organizations (SDOs) in small and medium-sized enterprises in the fish food production industry.
Design/methodology/approach: The study employed repetitive questionnaire assessments and workplace evaluations, including the use of measuring devices. The prediction results were compared with the evaluation of the ergonomics of the implemented EIs in the organization.
Findings: Promising prediction results were obtained regarding the employee's task load. The predictions indicate the validity of applying EIs more broadly to achieve benefits for SDO. The results show a positive impact of automation on reducing the overall task load.
Research limitations/implications: A limitation of the study is the sample size due to employment in a small enterprise and the limitations of the FCM Expert program.
Practical implications: The study provides an analysis of the possibilities of applying ergonomic interventions (EI) in the fish food production industry and can be used to support decision-making in organizations that prioritize sustainable development.
Social implications: The subject matter addressed in this study is important for ensuring human well-being by shaping appropriate working conditions.
Originality/value: The originality of the study lies in the creation of a model for predicting the impact of ergonomic interventions (EI) on sustainable development outcomes (SDO) in the niche food industry of fish food production.
Keywords: management, sustainable development of organizations, small and medium-sized enterprises, ergonomic interventions, fuzzy cognitive maps.
Category of the paper: Research paper and Case study.

1. Introduction

1.1. Sustainable development of the organization

The concept of sustainable development (SD) refers to meeting the needs of the present generation without compromising the ability of future generations to meet their own environmental, social, and economic needs in the short, medium, and long term. This concept has been extended to the organizational level, resulting in the notion of sustainable development of organizations (SDO). There are numerous reasons for balanced efforts toward SDO, encompassing economic, social, and environmental dimensions (Bolis, Brunoro, Sznelwar, 2014). The social dimension is often considered the weakest and most neglected in current research (Gajšek et al., 2022). The SDO concept is defined through various interpretations and approaches, highlighting its complexity. SDO associated with the social dimension includes aspects of work. Sustainable work is perceived as work that enhances organizational performance while promoting the professional development and health of employees (Bolis et al., 2013), justifying efforts to integrate ergonomic research with SDO (Bolis, Brunoro, Sznelwar, 2014).

SDO (Sustainable Diversity Optimization) is a process optimization aimed at minimizing losses associated with achieving specific economic and social benefits (Poon et al., 2016). The main motivators of SDO are increasing organizational efficiency and improving company image. The importance of SDO in achieving workplace diversity is emphasized. Organizations leverage the power of diversity as a foundation for developing sustainable competitive advantage. Additionally, factors promoting the development of a sustainable environment conducive to attracting and retaining a diverse workforce are noted (McCann, Kohntopp, 2017). The organization's ability to retain its workforce in the face of demographic decline (Kowalczyk, 2024) is one of the key challenges, especially for niche industries with high workforce demands. One such challenge in Poland is the production of fish food – this constitutes a research gap, as there are few articles dedicated to this activity.

1.2. Ergonomic interventions in SDO

Haslam & Waterson (2013) argue that there is synergy between SD (and hence SDO) and ergonomics. Ergonomics focuses on well-being at work and understanding employment practices, SD-oriented products, and efficient work systems aiming to ensure occupational safety (Steimle, Zink, 2006), through optimizing interactions of anthropotechnical systems. Dekker et al. (2013) argue that SDO must consider the complexity and challenges in solving ergonomic problems. A sustainable future requires a paradigm shift involving greater diversity of dispersed systems. There is a need to integrate macro- and micro-ergonomic approaches for effective interventions addressing causes of safety, quality, and work productivity issues (Genaidy et al., 2009). Scott (2009) notes that ergonomic interventions (EI) should uplift societies. The integration of ergonomics and SDO has resulted in the concept of green ergonomics integrating social and environmental aspects in a bidirectional relationship (Thatcher, 2013). Understanding these specific interactions and their interconnectedness is crucial (Poon et al., 2016). It should be noted that not only EI management applies to SDO. The concept of SD is also used to ensure, among other things, the desired ergonomics of organizational processes, making them more flexible (Sarbat, Ozmehmet, 2020). EI is one of the main factors contributing to gaining a competitive advantage, sometimes determining market survival (Grabowski, Muraszkiewicz, 2017). Ergonomics through EI influences work improvements, stimulates organizational productivity growth, employee well-being, and supports environmental changes (Bolis, Brunoro, Sznelwar, 2014).

SDO depends, among other things, on sustainable quality of production, products, workplace, social, environmental, and economic factors, achieved directly or indirectly through considerations including ergonomic factors (Cinar, Bilodeau, 2022). Furthermore, ergonomic factors relate to the 17 SDGs in the workplace (Gajšek et al., 2022). Hence, ergonomic risk factors and the applied EI related to them are linked to SDO.

EI within the framework of SDO modeling are actions and solutions aimed at improving the quality of human-machine-environment interactions, and involve (Wróbel, Hoffmann, Czarnecki, 2020):

1. enhancing specific products, organizational processes, IT systems, or services, etc.,
2. innovations, such as new products, services, or applications resulting from innovative combinations of existing elements - synergistically enhancing the overall quality of the solution, or
3. inventions - fundamentally defining a new level of quality for a given solution.

Ergonomic interventions (EI) are implemented within organizations at the strategic, tactical, operational, and task levels. Interventions are introduced in relation to and through their distinctive resources (Marilungo et al., 2017) and resource relationships.

1.3. Purpose and scope of the article

The issues introduced in the management of EI in the context of SD in small and medium-sized organizations lead to setting a research objective. The aim of the article is to predict the impact of selected ergonomic interventions on variables of organizational sustainable development in small and medium-sized enterprises in the fish food production industry. Prediction includes scenarios resulting from managing EI and SDO. The scope of the article includes the application of fuzzy cognitive maps (FCM) and the following specific objectives: 1) selection and assessment of SDO characteristics for selected job positions and tasks, 2) selection of EI based on the assessment of SDO variables of analyzed tasks, 3) assessment of the impact of EI on SDO variables, 4) building a knowledge base and simulation models, 5) simulation implementation and evaluation of the impact of EI on SDO, 6) discussion of the obtained results and further research directions.

The article is divided into 5 chapters. Chapter 1 presents the background, rationale, aim, and scope of the study. Chapter 2 focuses on describing the research subject, including the SD and EI variables of the studied organization. Next, Chapter 3 outlines the methodology and scope of the research. The results obtained are discussed in Chapter 4. The work concludes with Chapter 5, which discusses the findings.

2. Production Process and EI in Shaping SDO

2.1. Variables of the Production Process and SDO

Sustainable Production Management (SPM) (the production process) is an integral part of business strategies that create durable and ethical production models. However, workplace and production issues such as delivery delays and assembly line stoppages exist. Moreover, working in unhealthy environments leads to stress, frustration, and anxiety. These issues contribute to a lack of competitive advantage, coupled with shift work, low human resource productivity, and insufficient well-being, which pose barriers to Sustainable Workplaces (SW) (Realyvásquez-Vargas et al., 2020).

Sustainable health and mental well-being are crucial for achieving Sustainable Development Objectives (SDO), especially for small and medium-sized enterprises. Health and mental well-being are particularly associated with SDG goals 8, 9, and 11: economic growth and prosperity, sustainable communities, innovation, and workplaces (job positions) (Cinar, Bilodeau, 2022). The research conducted in the article focused, among other things, on SW in job positions such as: 1) jar filling and capping station; 2) cooking station for products; 3) blanching and cooling station for products (Fig. 1).

a) b) c)

Figure 1. Workstations: a) filling and capping jars workstation; b) cooking products workstation; c) sterilizing and cooling products workstation.

Source: own study.

Table 1 lists the most frequently performed tasks and activities of the manufacturing process at selected workstations within the studied organization.

Table 1.
Tasks and activities (selected scope)

No. Task	Task	Examples of the most frequently performed tasks
1.	pouring fillings into jars	retrieving the sieve and scooping contents from the bowl; emptying the contents from the bottom of the crate and setting the crate aside on the floor
2.	filling jars with contents	staining and topping up water in the jar; fetching the bucket with the contents and pouring off excess water
3.	hand tightening jar lids	screwing on the jar lid and placing it on the content base; picking lids from the bucket and placing them on the jars
4.	removing jars from the boiler	retrieving and mounting sleeves on the hoist hook for jar contents; adjusting pressure in the samovar and standing
5.	cooling jars	transferring cooked jars with contents into crates; washing the content base pad with a hose

Source: own study based on research in the organization in question.

As presented by Cinar and Bilodeau (2022), there are no standard frameworks for ergonomic indicators. Furthermore, there is a limitation on quantitative indicators in ergonomic assessment. According to the research of Lin, Efranto, and Santosa (2021), the best ergonomic indicators encompass well-being, safety issues, workplace comfort, musculoskeletal health, and environmental factors.

The dictionary definition of a sustainable system suggests that it is a system capable of enduring indefinitely (Costanza, Patten, 1995). However, this definition does not answer the questions: 1) which sustainable system should be considered; and 2) what time frames are considered sustainable (Costanza, Patten, 1995) in the context of ergonomic factors (Thatcher, Yeow, 2016). Table 2 presents the classification of selected SDO variables based on a literature review and organization.

Table 2.
Variables of sustainable manufacturing process

Variable of the manufacturing process	FCM variable symbol	FCM model variable
on-time delivery	C1 C2	task completion on time operation/task delay time
time complexity and variability of operations/ tasks	C3 C4	operation/task execution time task variability
resource consumption	C5 C6 C7	electricity consumption water consumption reported health complaints
waste generation	 C8 C9	produced waste: a) glass b) organic waste
downtime	C10	downtime
product quality	 C11 C12 C13 C14	percentage of correct products out of 100 produced in a task: a) color and size assessment of fill b) proportion assessment of fill c) lid tightening assessment d) packaging cleanliness assessment
performance	C15	number of manufactured products
efficiency	C16	number of products produced/resources used + waste generated
productivity	C17	level of efficiency over time

Cont. table 2.

environmental noise	C18	environmental noise level (peak A-weighted sound level at workstation)
height of work surfaces	C19	minimum height of work surface [cm]
	C20	variation in height of work surface [cm]
mass and size of moved objects	C21	mass of moved objects (REBA method)
access to workspace	C22	accessibility – forced body position
frequency of object movement	C23	frequency of object movement
task and activity complexity	C24	average NASA-TLX rating
workload severity	C25	workload severity (Heart Rate – HR measurement)
breaks for recovery	C26	assessment of work pace enforcement
temperature of the means of work	C27	maximum temperature of working means [°c]
worker mental workload	C28 C29 C30 C31 C32 C33	mental workload physical workload time workload performance workload effort workload frustration
postural workload	C34	postural workload (REBA method)

Source: own study based on literature (footnotes in the text under the table).

Referring to SPM variables, Fazlollahtabar (2016) notes that on the assembly line where product deliveries were delayed, the cause was poor production efficiency. Regarding downtime and failures (Sonmez, Testik, Testik, 2018), researchers confirm that they decrease productivity and production efficiency (Ren et al., 2015), leading to increased losses and costs (Sonmez, Testik, Testik, 2018). Downtimes contribute to delays. Downtimes result from raw material shortages (Realyvásquez-Vargas et al., 2020), which are a critical issue (Peng, Zhou, 2018).

One of the main determinants of the mentioned workplace indicators is workstation design. Workstation design affects body posture (Kushwaha, Kane, 2016) and workers' movements (Gaudez, Gilles, Savin, 2016), leading to musculoskeletal disorders, thereby impacting productivity and well-being (Gómez-Galán et al., 2018) and causing high production costs (Realyvásquez-Vargas et al., 2020). Additionally, material handling processes, inefficient movements, and body postures negatively affect product quality, generate long production cycle times, and result in inefficient use of human resources (El-Namrouty, Abushaaban, 2013). Repetitive movements can cause fatigue and loss of concentration, increasing the likelihood of errors, affecting productivity and safety (Yeow et al., 2014). Anthropometric workstations reduce raw material consumption and extend the use of technical facilities (Realyvásquez-Vargas et al., 2020).

2.2. EI in fish food production

During the research in the organization, two EI were implemented (Fig. 2). Ensuring high quality of SPM and SW both before and after implementing EI requires continuous improvement, monitoring, and ergonomic analysis. Real-time monitoring of employees' status and recording their actions allows diagnosing the causes and consequences of changes in work situations, providing data for decision-support models. Diagnosis forms the basis for optimizing work processes, which is crucial for improving productivity and reducing costs in modifying work systems to enhance safety and ergonomics (Romero et al., 2016; Butlewski et al., 2020). Measuring operator reactions generates knowledge about interactions and possibilities for system modifications based on objective data (Peruzzini, Grandi, Pellicciari, 2020).

Figure 2. Complex systems of polygamous holes made from one cluster to several coal deposits.

Source: own study and https://tiny.pl/djccf.

Regarding the SDO variables of the analyzed tasks, potential ergonomic interventions (EI) were identified (Table 3), which were considered in the study.

Table 3.
Selected ergonomic interventions

Task (tab. 1)	EI No	EI
T1	1	using manual trays for measuring input material
	2	using automated equipment (dispenser)
T2	3	using liquid measuring device
	4	using automated equipment (fluid dispenser/filler)
T3	5	using automated equipment (jar capper)
	6	using automated lid feeder
T4	7	thermal and waterproof gloves
T5	8	setting the sterilizer at a height of 1.2 m
	9	using automated air blower above the counter
	10	using pneumatic balancer with gripper
	11	using a loading robot

Source: own study.

3. Method and scope of research

Regarding the purpose of the study and the research subject, the method and scope of the research were selected. The method, tools, and scope of the research are defined by the applied procedure to achieve the specific objectives of the study (Chapter 1.3), which involved:

1. systematic literature review concerning SDO variables and the impact of SDO variables and EI in companies in the fish food production industry; ResearchGate and Scholar databases were utilized; initially, 208 articles were collected; 83 articles were used;
2. selection of tasks and EI based on the assessment of SDO characteristics in workstations; evaluation of 16 tasks at 6 workstations; data suggesting EI implementation for most tasks was obtained; this article focused on the first 5 tasks of the production process; SDO assessment was conducted using an evaluation questionnaire consisting of 18 questions (for variables C1-2, 5-17, 22-23, and 26 – Table 2) with a 5-point rating scale, where 1 indicated the weakest value and 5 the strongest value of the variable (the scale was complemented by the response: no variable); characteristics of other SDO variables (Table 2) were established based on workstation studies and adopted rating scales; daily work photography was used, noise measurement (IM-02_m meter), workload measurement (Polar H10 meter), task load assessment (NASA-TLX; 9 measurement trials), and postural load assessment (REBA method); concerning the objective of the study, assessments of individual tasks were compiled and quantified using linear transformation method (Figure 6);
3. assessment of the impact of EI implementation on SDO variables – based on questionnaire assessment (5-point impact rating for previously defined relationships – according to literature review) of company employees before EI implementation and based on implemented EI (EI5 and 7) and workstation assessments;
4. construction of models for the interaction of SDO and EI variables using fuzzy cognitive mapping (FCM) method and FCM Expert application;
5. simulations and evaluation of the impact of EI on SDO.

The work was concluded with a summary of the obtained results and identification of further research directions.

4. Research results

4.1. Results of workplace studies

Acoustic conditions in the production hall vary depending on the tasks and remain within acceptable limits. The highest noise levels occur during task number 5 (80 dB). Significant differences in task completion time were observed in tasks 5, 4, and 3 (Figure 3). The implemented EI only slightly reduced the duration of tasks. In the case of task 3, this was due to transferring only part of the tasks from the worker to the device.

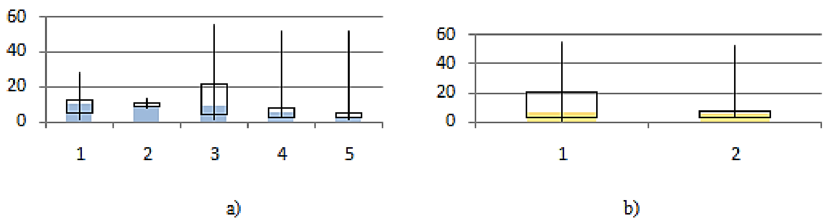

Figure 3. Duration of activities [s] for tasks T1-5: a) before EI; b) after EI (1 refers to EI5; 2 refers to EI7).

Source: own study.

The variation in task load assessment results for the studied tasks before the implementation of EI is presented in Figure 4 (blue charts). It should be noted that in task 3, the task load assessments (mental, physical, and effort load) are highest; the longest time load occurs in tasks 2 and 4; task 2 also has the highest performance requirements, and the highest noticeable frustration was observed in task 4.

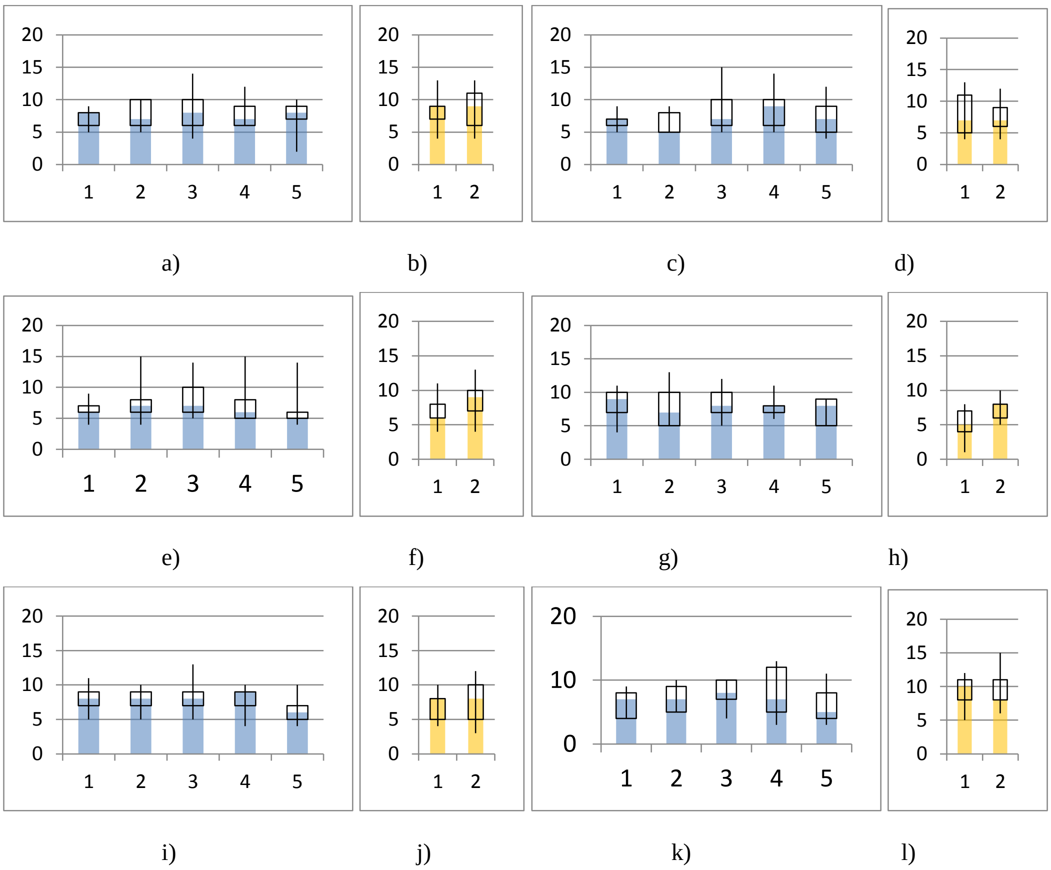

Figure 4. Task load according to NASA-TLX during tasks T1-5: a), b) mental load; c), d) physical load; e), f) temporal load; g), h) performance load; i), j) effort load; k), l) frustration and stress load (blue charts represent assessments before EI; orange charts represent assessments after EI).

Source: own study.

There was a noticeable decrease in temporal load (for task 3), while for task 4, the temporal load increased. There was also a significant reduction in performance and effort load for task 3. However, frustration slightly increased for task 4 with EI7 and for task 5 with EI5 (Figure 4 – orange charts).

There was no clear change in workload severity based on HR measurement. Both before and after EI implementation, the results generally ranged between 80 and 105 HR.

The results of postural load are presented in Figure 5.

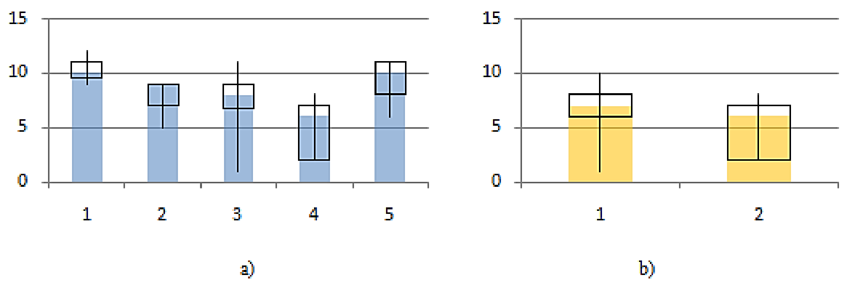

Figure 5. Differentiation of postural load according to the REBA method during the execution of tasks T1-5: a) before EI; b) after EI.

Source: own study.

The implemented EIs did not noticeably affect the reduction of postural load (Figure 5).

4.2. Quantification of the results from workplace studies and questionnaires

Individual results of SDO variables were compiled, and the results of measurement studies were subjected to linear transformation, establishing the differentiation of characteristic values of SDO variables for the studied tasks (Figure 6). Quantification of SDO variable characteristics was dictated by achieving required values in the FCM method. Values of SDO variables were determined based on the median [S] (Table 5), which serve as input data for simulations.

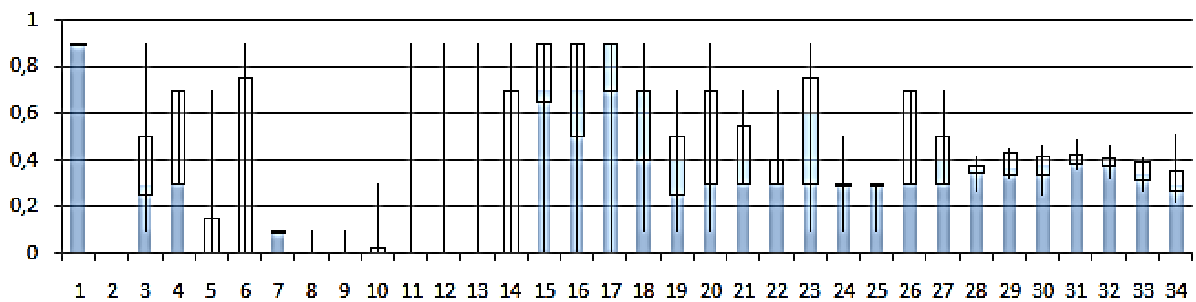

Figure 6. Differentiation of SDO characteristics based on the averaged assessment results of tasks 1-5.

Source: own study.

The quantified average impacts of EI on SDO variables are presented in Table 4.

Table 4.
Quantification of averaged impacts of EI on SDO variables according to employee assessments

		EI										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
SDO variable	**3**	-0,2	-0,9	-0,1	-0,9	-0,6	-0,6	0,9		-0,6	0,2	-0,4
	4	0,1	-0,5	0,2	-0,5	-0,6	-0,5	0,1		-0,6		0,3
	5		0,8		0,8	0,7	0,4			0,7		0,7
	6			-0,2	-0,7							
	7		-0,1		-0,2	-0,3	-0,2	-0,7	-0,5		-0,6	-0,3
	9	-0,5	-0,5									
	10		0,1		0,2	0,1	0,2			-0,1		0,2
	11	0,4	0,2									
	12	0,6	0,9	0,4	0,9							
	13					0,4						
	18		0,7		0,5	0,6	0,7			0,9		0,6
	19								0,6			
	20											-0,8
	21	-0,1	0,2	-0,1	-0,8		-0,2			-0,2	-0,9	-0,9
	22		0,2		0,5	0,4	0,4	-0,1	0,8	0,7	-0,3	0,7
	23	-0,2	-0,8	-0,1	-0,9	-0,6	-0,3			-0,6		-0,9
	24	0,3	0,3	0,1	0,2	0,1	0,1	0,1		-0,3	0,2	0,3
	25	-0,2	-0,6	-0,2	-0,6	-0,6	-0,6		-0,7	-0,3	-0,7	-0,9
	26		0,3		0,6	0,1		-0,1		-0,5		-0,6
	27							-0,7				-0,8
	28	-0,2	0,2	-0,1	0,4		-0,2	-0,1		-0,3	0,2	0,3
	29	-0,2	-0,6	-0,1	-0,8	-0,3	-0,6		-0,7	-0,4	-0,7	-0,8
	30	-0,2	0,4	-0,2	0,7	-0,7	-0,7		-0,4	-0,5	0,2	0,4
	31	0,2	-0,3	0,1	-0,3	-0,3	-0,7		-0,3	-0,2	0,2	-0,3
	32	-0,2	0,3	-0,2	-0,8	-0,7	-0,4		-0,7	-0,3	-0,7	-0,7
	33	-0,2	-0,2	-0,1	-0,3	-0,5	-0,3	-0,5	-0,3	-0,4	0,2	0,2
	34	-0,1	-0,6	-0,1	-0,7		-0,5		-0,7	-0,4	-0,7	-0,8

The variables of SDO on which EI have no impact were omitted from Table 4.

Source: own study.

4.3. The construction of a knowledge base using the FCM method

Prediction models of the impact of EI on SDO variables were built based on the FCM method using the FCM Expert application (Nápoles, Gonzalo et al., 2018). The concepts of maps represent SDO variables and EI (Tables 2 and 3). Only relationships were selected that describe interactions characterized by: 1) an increase in the value of concept Ci input and an increase in the value of concept Ci output, 2) an increase in the value of concept Ci input and a decrease in the value of concept Ci output. In accordance with the objective of the study and the scope of prediction, 11 maps were constructed. All maps were based on the same data selected for prediction scenarios (Chapter 4.4).

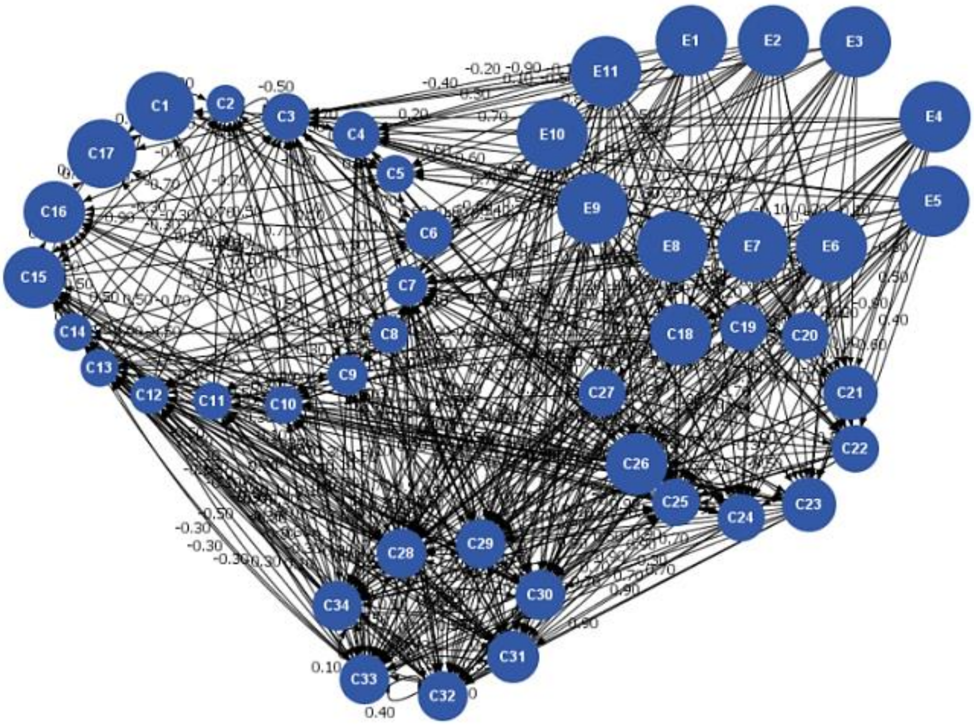

Figure 7. The general structure of the FCM map built using the FCM Expert application.
Source: own study.

The concepts were assigned values based on the results of studies in the organization and quantification.

4.4. Procedure and scope of prediction

The prediction procedure and scope encompassed the following simulation impact scenarios: 1) states of work system variables without EI implementation; 2) production process variables on employee task loads; 3) workplace conditions variables on task loads; 4) basic EI on task loads; 5) EI requiring automation and robotics on task loads; 6) basic EI on production process variable states; 7) EI requiring automation and robotics on production process variable states; 8) basic EI on workplace conditions variables; 9) EI requiring automation and robotics on workplace conditions variables; 10) implemented EI7 on task loads (task 3); 11) implemented EI5 on task loads (task 4).

In addition, simulations were conducted to assess the impact of individual EI on task load variables (Table 6). The simulations were performed using the following inference (calculation) parameters: activation rule: kosko’s activation rule with self-memory; Transfer fuction: sigmoid function; Slop: 1; Offset: 0.1; Stoping criterion: 10 interaction.

4.5. The prediction results of EI impact on SDO variables

The prediction results are shown in Tables 5 and 6. Table 5 captures the results of the first 11 simulations.

Table 5.
The prediction results

Model variable no	Initial values of task variables 1-5 [S]	Initial values of variables for tasks 3-4	Simulation scenario										
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
C1	0,9		0,12	0,13				0,54	0,71				
C2	0		0,89	0,80				0,34	0,19				
C3	0,3		0,88	0,87				0,52	0,01				
C4	0,3		0,75	0,52				0,67	0,09				
C5	0		0,90	0,89				0,85	1,00				
C6	0,3		0,71	0,73				0,84	0,72				
C7	0,1		1,00	0,97				0,23	0,30				
C8	0		0,63	0,63				0,61	0,61				
C9	0,1		0,76	0,72				0,16	0,15				
C10	0		0,89	0,87				0,68	0,81				
C11	0		0,05	0,15				0,74	0,69				
C12	0		0,05	0,15				0,85	0,93				
C13	0		0,05	0,13				0,63	0,74				
C14	0		0,05	0,15				0,63	0,63				
C15	0,9		0,01	0,01				0,95	0,97				
C16	0,7		0,03	0,08				0,65	0,73				
C17	0,9		0,49	0,30				0,69	0,81				
C18	0,7		0,63		0,63					0,63	0,99		
C19	0,3		0,72		0,72					0,84	0,68		
C20	0,3		0,63		0,63					0,63	0,37		
C21	0,5		0,63		0,63					0,29	0,13		
C22	0,3		0,55		0,55					0,71	0,98		
C23	0,5		0,70		0,74					0,67	0,02		
C24	0,3		0,87		0,82					0,89	0,86		
C25	0,3		1,00		1,00					0,86	0,11		
C26	0,7		0,97		0,94					0,83	0,68		
C27	0,3		0,63		0,63					0,40	0,37		
C28	0,38	0,42/0,4	0,98	0,84	0,95	0,57	0,74					0,60	
C29	0,37	0,43/0,44	0,99	0,89	0,96	0,16	0,03						0,53
C30	0,39	0,42/0,39	1,00	0,98	0,95	0,43	0,50						0,40
C31	0,4	0,42/0,4	0,96	0,87	0,87	0,69	0,11						0,53
C32	0,39	0,42/0,39	0,99	0,82	0,98	0,15	0,07						0,40
C33	0,36	0,39/0,4	1,00	0,98	0,98	0,34	0,20					0,47	0,47
C34	0,39	0,36/0,25	0,97	0,73	0,95	0,18	0,05						

Source: own study.

Table 6 presents the results of the impact of individual EI on employee task load variables.

Table 6.
The results of predicting individual EI impacts on employee task loads.

Model variable no	EI										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
C28	0,57	0,69	0,60	0,74		0,57	0,60	-	0,53	0,69	0,71
C29	0,57	**0,43**	0,60	**0,37**	0,53	**0,43**	-	**0,40**	0,50	**0,40**	**0,37**
C30	0,57	0,74	0,57	0,80	**0,40**	**0,40**	-	0,50	0,47	0,69	0,74
C31	0,69	0,53	0,66	0,53	0,53	**0,40**	-	0,53	0,57	0,69	0,53
C32	0,57	0,71	0,57	**0,37**	**0,40**	0,50	-	**0,40**	0,53	**0,40**	**0,40**
C33	0,57	0,57	0,60	0,53	0,47	0,53	0,47	0,53	0,50	0,69	0,69
C34	0,60	**0,43**	0,60	**0,40**	-	0,47	-	**0,40**	0,50	**0,40**	**0,37**

The bolded results indicate improvement or comparable ergonomic outcomes due to the implementation of EI compared to the initial values of SDO variables.

Source: own study.

5. Summary

Comparison of the results from workstations evaluated after the implementation of EI and the predicted impact of EI on task load reveals that the model demonstrated high prediction accuracy. Only for a subset of variables, accurate predictions were not obtained. The evaluation of the predicted impact of EI on production process variables or workstations requires adjustments. Nevertheless, a large portion of the results aligns with general knowledge, indicating that the developed prediction model is reliable. The originality of this work lies in the creation of a prediction model for the impact of EI on SDO within the niche food production industry for fish.

By comparing the data from tables 5 and 6, it can be observed that the application of a greater number of EIs will positively influence ergonomics and thus SDO. The use of automated solutions, which generally improve ergonomics and SDO, can be particularly beneficial in this regard. However, the application of automation may adversely affect mental and time-related workloads.

The limitations of the study include the research sample size due to the scale of employment in a small enterprise and the limitations of the FCM Expert program, particularly the constraints related to the transfer functions of concept values. The functions are the same for all relationships, which is a limitation.

The study provides an analysis of the potential application of EI in the fish food production industry and can serve as a decision-making aid for organizations focused on sustainable development. Continuous improvement of the organization and its methods, including further research on the impact of EI on SDO, is necessary. Predictions of the impact of SDO variables, including ergonomic ones, can serve as an alternative in supporting SDO management for small and medium-sized enterprises that do not have advanced decision support systems and highly automated production lines

The topic addressed in this study is important for ensuring human well-being by shaping proper working conditions and efficiency, as confirmed by the extensive literature cited in the introduction of the work.

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References

1. Bolis, I., Brunoro, C.M., Sznelwar, L.I. (2014). Mapping the relationships between work and sustainability and the opportunities for ergonomic action. *Applied Ergonomics, 45*(4), 1225-1239.
2. Bolis, I., Morioka, S.N., Brunoro, C.M., Sznelwar, L.I. (2013). Sustainability policies and Corporate Social Responsibility (CSR) Ergonomics contribution regarding work in companies. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, Vol. 57, No. 1*. Los Angeles, CA: SAGE Publications, pp. 1080-1084.
3. Butlewski, M., Dahlke, G., Drzewiecka-Dahlke, M., Hankiewicz, K., Górny, A., Gajsek, B. (2020). Use of the methodology of network thinking for a fatigue criteria investigation based on the example of mining companies. *Tehnički Vjesnik [Technical Gazette], 27*(4), 1037-1043.
4. Cinar, A.B., Bilodeau, S. (2022). Sustainable workplace mental well-being for sustainable SMEs: How? *Sustainability, 14*(9), 5290.
5. Costanza, R., Patten, B.C. (1995). Defining and predicting sustainability. *Ecological Economics, 15*(3), 193-196.
6. Dekker, S.W., Hancock, P.A., Wilkin, P. (2013). Ergonomics and sustainability: Towards an embrace of complexity and emergence. *Ergonomics, 56*(3), 357-364.
7. El-Namrouty, K.A., Abushaaban, M.S. (2013). Seven wastes elimination targeted by lean manufacturing case study "Gaza strip manufacturing firms". *International Journal of Economics, Finance and Management Sciences, 1*, 68-80.
8. Fazlollahtabar, H. (2016). Parallel autonomous guided vehicle assembly line for a semi-continuous manufacturing system. *Assembly Automation, 36*, 262-273.
9. Gajšek, B., Draghici, A., Boatca, M.E., Gaureanu, A., Robescu, D. (2022). Linking the use of ergonomics methods to workplace social sustainability: The Ovako working posture assessment system and rapid entire body assessment method. *Sustainability, 14*(7), 4301.
10. Gaudez, C., Gilles, M.A., Savin, J. (2016). Intrinsic movement variability at work: How long is the path from motor control to design engineering? *Applied Ergonomics, 53*, 71-78.
11. Genaidy, A.M., Sequeira, R., Rinder, M.M., A-Rehim, A.D. (2009). Determinants of business sustainability: An ergonomics perspective. *Ergonomics, 52*(3), 273-301.
12. Gómez-Galán, M., Pérez-Alonso, J., Callejón-Ferre, Á.-J., Sánchez-Hermosilla-López, J. (2018). Assessment of postural load during melon cultivation in Mediterranean greenhouses. *Sustainability, 10*, 2729.
13. Grabowski, S., Muraszkiewicz, M. (2017). Modelowanie ekosystemów informacyjnych dla innowacyjnych społeczności programistycznych. *Zagadnienia Informacji Naukowej - Studia Informacyjne, 55*(2(110)), 30-45.

14. Haslam, R., Waterson, P. (2013). Ergonomics and sustainability. *Ergonomics, 56*(3), 343-347.
15. Kowalczyk, E. (2024). Proces starzenia się ludności Polski. Przyczyny i skutki. *Wieś i Rolnictwo, 1(202)*, 7-40.
16. Kushwaha, D.K., Kane, P.V. (2016). Ergonomic assessment and workstation design of shipping crane cabin in steel industry. *International Journal of Industrial Ergonomics, 52*, 29-39.
17. Lin, C.J., Efranto, R.Y., Santoso, M.A. (2021). Identification of workplace social sustainability indicators related to employee ergonomics perception in Indonesian industry. *Sustainability, 13*(19), 11069.
18. Marilungo, E., Papetti, A., Germani, M., Peruzzini, M. (2017). From PSS to CPS design: A real industrial use case toward Industry 4.0. *Procedia CIRP, 64*, 357-362.
19. McCann, J., Kohntopp, T. (2017). Developing a sustainable environment for workplace diversity. *International Journal of Sustainable Strategic Management, 5*(4), 347-365.
20. Nápoles, G., Falcon, R., Papageorgiou, E., Bello, R., van den Herik, H.J. (2018). FCM Expert: Software tool for scenario analysis and pattern classification based on fuzzy cognitive maps. *International Journal on Artificial Intelligence Tools*, *27*(7), 1860010. https://doi.org/10.1142/S0218213018600102.
21. Peng, T., Zhou, B. (2018). Scheduling multiple servers to facilitate just-in-time part-supply in automobile assembly lines. *Assembly Automation, 38*, 347-360.
22. Poon, W.C., Herath, G., Sarker, A., Masuda, T., Kada, R. (2016). River and fish pollution in Malaysia: A green ergonomics perspective. *Applied Ergonomics, 57*, 80-93.
23. Realyvásquez-Vargas, A., Arredondo-Soto, K.C., Blanco-Fernandez, J., Sandoval-Quintanilla, J.D., Jiménez-Macías, E., García-Alcaraz, J.L. (2020). Work standardization and anthropometric workstation design as an integrated approach to sustainable workplaces in the manufacturing industry. *Sustainability, 12*(9), 3728.
24. Ren, C., Barlotti, C., Cohen, Y., Frangipane, B., Garofalo, M., Cozzari, G., Metz, C. (2015). Re-layout of an assembly area: A case study at Bosch Rexroth Oil Control. *Assembly Automation, 35*, 94-103.
25. Romero, D., Stahre, J., Wuest, T., Noran, O., Bernus, P., Fast-Berglund, Å., Gorecky, D. (2016). Towards an operator 4.0 typology: A human-centric perspective on the fourth industrial revolution technologies. *Proceedings of the international conference on computers and industrial engineering (CEI46)*, Tianjin, China, 29-31.
26. Sarbat, I., Ozmehmet Tasan, S. (2020). A structural framework for sustainable processes in ergonomics. *Ergonomics, 63*(3), 346-366.
27. Scott, P.A. (2008). Global inequality, and the challenge for ergonomics to take a more dynamic role to redress the situation. *Applied Ergonomics, 39*(4), 495-499.

28. Sonmez, V., Testik, M.C., Testik, O.M. (2018). Overall equipment effectiveness when production speeds and stoppage durations are uncertain. *International Journal of Advanced Manufacturing Technology, 95*, 121-130.
29. Thatcher, A., Yeow, P.H. (2016). Human factors for a sustainable future. *Applied Ergonomics, 57*, 1-7.
30. Wróbel, K., Hoffmann, T., Czarnecki, K. (2020). Management of ergonomic interventions when modeling the technological processes in the Industry 4.0. *Proceedings of the 36th International Business Information Management Association Conference (IBIMA)*, Granada, Spain, 4-5 November 2020, pp. 3202-3211.
31. Yeow, J.A., Ng, P.K., Tan, K.S., Chin, T.S., Lim, W.Y. (2014). Effects of stress, repetition, fatigue and work environment on human error in manufacturing industries. *Journal of Applied Sciences, 14*, 3464-3471.