SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2024
ORGANIZATION AND MANAGEMENT SERIES NO. 200

THE IMPACT OF MACROERGONOMIC FACTORS ON ORGANIZATIONAL RISK IN PRODUCTION SYSTEMS – PRELIMINARY ANALYSIS OF THE RELATIONSHIP

Anna STASIUK-PIEKARSKA[1*], Aleksandra DEWICKA-OLSZEWSKA[2]

[1] Department of Engineering Management, Institute of Safety and Quality Engineering, Poznań; Anna.stasiuk-piekarska@put.poznan.pl, ORCID: 0000-0001-6021-9694
[2] Department of Engineering Management, Institute of Safety and Quality Engineering, Poznań; Aleksandra.dewicka-olszewska@put.poznan.pl, ORCID: 0000-0003-4683-6519
* Correspondence author

Purpose: The aim was to indicate to decision-makers the factors that should be given the most attention so that the level of macroergonomics is as high as possible, while reducing the level of organizational risk.
Design/methodology/approach: The article presents the concept and functions of macroergonomics, as well as organizational risk. A literature review was performed in an attempt to identify the areas of influence of these elements as precisely as possible. Then, an attempt was made to conduct a preliminary analysis of the connections between both factors in the organization's activities, with particular emphasis on the production system.
Findings: As a result of the analyses, organizational preparation of production was considered an important element. At the same time, when analyzing impacts, the level of sustainability seems to be an often influencing element. These factors have an inversely proportional impact on organizational risk. At the same time, the impact of the organization's vision and mission on proactive organizational risk management was identified.
Research limitations/implications: The research is a preliminary analysis. It is necessary to continue to identify influence factors and the connections between factors, as well as to assess their strength and time perspective of influence.
Practical implications: Macroergonomics, as well as risk management, are an important aspect in the conscious management of the production system. The article presents the concept and functions of macroergonomics, as well as organizational risk. The results of the study will allow for a broader view of business management issues and support for appropriate areas of influence.
Social implications: Conducted research at a further stage may support the implementation of macroergonomics in work systems by influencing the identified impact factors. Thus, they can support the proper design of production systems that take into account the human factor and its specificity.
Originality/value: Searching for connections between macroergonomics and organizational risk in production systems.
Keywords: macroergonomics, organizational risk, production systems, network thinking methodology.
Category of the paper: Research and conceptual paper.

1. Introduction

The modern situation of enterprises focused on global competition makes it necessary to proactively manage business risk in order to prevent undesirable situations and at the same time take advantage of the opportunities arising from the changing reality. At the same time, an aging society and the need to compete for the best employees. The ergonomics of a single workstation may not be enough, hence the need to look at the production system as a whole, which must be not only functional and harmonized with each other, but also optimal and synergistic (Wyrwicka, 2003). Hence, at the organizational level we should talk about macroergonomics.

At the same time, it should not be forgotten that the introduction of both ergonomics and a risk management system generates costs in the company. Therefore, the authors decided to analyze the relationships between these issues, looking for factors that may influence each other in a direct proportional (+) or inverse proportional (-) way. This may allow you to identify elements that will allow for better implementation and/or support of both issues within the operation of production systems.

Also from the point of view of meeting legal and normative requirements, both ergonomics and risk management are activities that are indicated not only in legal regulations (e.g. in the Labor Code - ergonomics, in CSRD - risk management and the social area, which may also concern care for the health and life of employees). Therefore, these activities should be treated as a long-term investment that allows you to obtain not only image-related benefits, but above all financial ones - resulting from a more conscious and efficient management of available resources (Dragun).

2. Production systems and its influences

The production system is defined as separate elements within production activities that interact with each other and may be in relationship with the environment (Bertalanffy, 1984, p. 68). It is considered to be purposeful and organized in the material, information and energy spheres. Moreover, it is exploited by humans for the production of specific material products in order to meet the needs of consumers (Kawecka-Endler, 2004; Stasiuk-Piekarska et al., 2020). Mazurczak believed that it is "static and dynamic combinations of teams transforming inputs (processes, work items, means of work, information) into outputs", which are in the form of a material (products) or immaterial form (services, information) (Mazurczak, 2002, p. 7). Moreover, Lis and Fertsch emphasize that production systems are an entity within which appropriate labor resources are grouped, such as: machines, devices, tools or installations, and human resources - labor, for the purposes of transforming objects at work in the form of

input materials, into products that are output elements (Lis, 1982; Fertsch et al., 2011). The aim of the above is to meet the customer's needs in a satisfactory manner (not always to the highest degree) (Józefowska).

The Nadler work system model can also be a description of the production system which includes (after: Rzeszotarska-Wyrwicka, 1995):

- tasks resulting from the function or purpose for which the system was created;
- input elements such as: work items, information, media, disposable tools, auxiliary materials;
- employees - as entities that often undertake activities on their own or activate passive elements of the system;
- a work process (e.g. production) that enables the transformation of input elements into output elements, this may involve the use of know-how or the selection of the optimal technology in terms of the adopted criteria;
- means of work such as: infrastructure and permanent equipment;
- output elements, including products, waste, feedback;
- interactions with the environment - closer (working conditions) and further (other departments, suppliers, cooperators, recipients...).

All elements of the production system interact with each other. It is worth noting that the production system is an open system because it is influenced by external factors. From the point of view of risk management in production systems, they are an important element because managers do not always have influence on them or are able to eliminate the effects of their impact (Stasiuk, Werner, 2012). Figure 1 shows the production system model adopted for the purposes of this work.

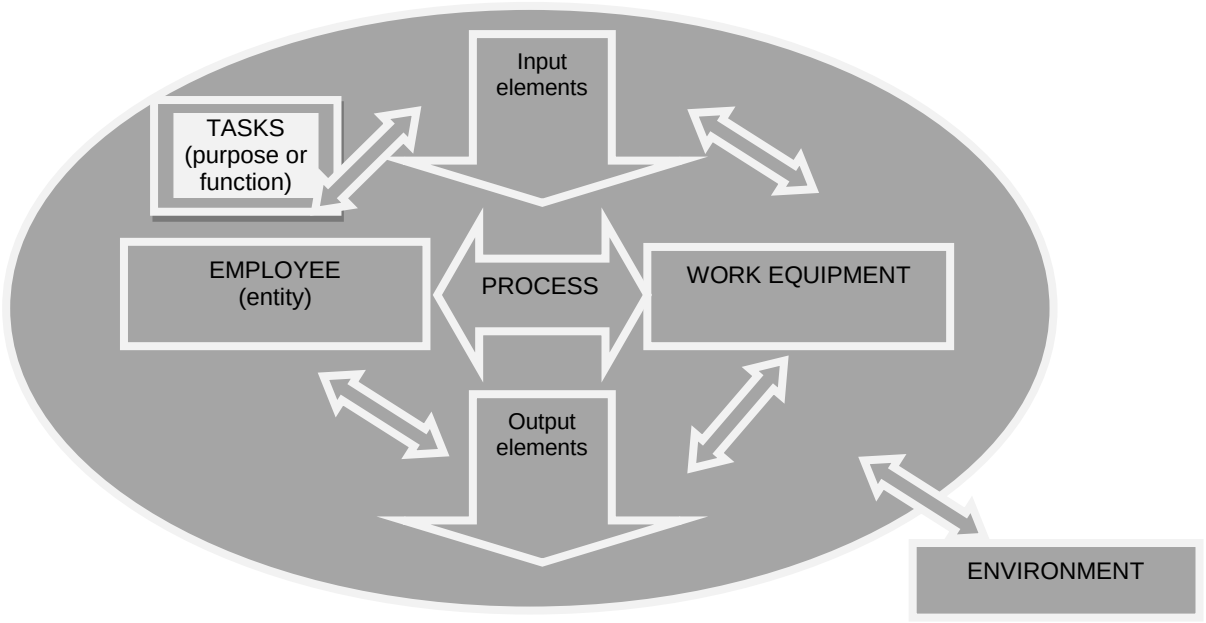

Figure 1. Production system according to Nadler's concept (1967).

Source: Rzeszotarska-Wyrwicka, 1995, p. 7.

Analyzing subsequent impacts on the production system, one also notices the impact of organizational and production conditions affecting the production structure, as well as the control system and the methods, technologies and information systems used in its operation (Senger, 1998). In terms of the tasks performed, the elements of the system create its structure reflecting the way they are divided, as well as the deliberately established relationships between them - it should be strived for it to display the features of an organized whole (i.e. functionality, optimality, harmony and synergy. It should also be noted that the conditions organizational and production factors constitute an element determining the level of work safety, and to a narrower extent, work ergonomics - both of an individual workstation (microergonomics) and in the context of the entire production system - macroergonomics.

H.W. Hendrick distinguished three stages of the development of ergonomics. He is the creator of the term macroergonomics - this phrase was first used in the article Macroergonomics: A Concept whose Time has Come (1987). Three stages of ergonomics are described there - the first two concern microergonomics, and the third - called "macroergonomic design". An industrial enterprise was considered the object of design. It is treated as a system whose internal structure and internal structure depend on the external environment. It is assumed that "it is impossible to prepare a good microergonomic design and at the same time achieve high system efficiency without taking into account the macroergonomic dimension" (Jasiak, 2016). As part of macroergonomics, attention was drawn to the need to assess the organization from top to bottom, a systemic approach to enterprises, also to system design (Hendrick, Kleiner, 2001; Jasiak, 2016). This principle is consistent with the praxeological approach to the system that one cannot design an organization without seeing it as a whole. It is also important from the point of view of risk management of the organization's activities. Kleiner is of the opinion that by "building upon systems ergonomics, macroergonomics provides specific and refined methodologies and tools linked to an underlying theory for work system analysis and design such as Macroergonomic Analysis of Structure and macroergonomic analysis and design" (Kleiner, 2023).

The most important factors that contributed to the need to isolate the concept of macroergonomics include:

- development of new technologies and increase in automation,
- aging of society in industrialized countries,
- psychological changes in the workforce,
- increase in global competition,
- limited area of microergonomics and resulting disputes regarding ergonomics (Jasiak, 2016).

Therefore, macroergonomics was created as an extension of the scope of microergonomics so that it is possible to analyze and improve a multi-object system (e.g. an organization or a production system), within which both the internal structure and internal relations depend on the external environment. As part of macroegonomic design, the entire system is analyzed, with particular emphasis on the workstations used, the people participating in it, as well as the relationships between them and with the system's environment. It seems important that it covers the entire relationship between humans and technology. They have an impact not only in the work environment, but also on the morphophysiological, social and mental sphere of man. (Jasiak, Misztal, 2004, after: Jasiak, 1983). This is especially important now, when human-collaborative robot interactions occur more and more frequently in the production system (Faccio et al., 2023).

3. Organizational risk

In various types of organizations, attention is paid more and more often and more consciously to the aspect of risk management. Referring to the definition of risk, it can be concluded that risk is present in every area of life as a result of the lack of certainty of events regarding the future. Historical references to risk date back to 1725, when R. Cantillon introduced the concept of risk and uncertainty in the context of economic thought. However, it was only in 1921 that Knight pointed out the impact of risk on the world of classical economics (Klimczak, 2008; Bochenek, 2012). It is worth noting that in 1974 Galbraith drew attention to the tasks of organizations, which involve processing information about uncertainties in the environment and taking actions to deal with them. This is referred to as the theory of organizational information processing (TOIP) (Tian, Xin Xu, 2015). The same author also expressed the opinion (1974) that the economy is taken over by large corporations, controlled by management experts who create the so-called technostructure. Its aim is to build and consolidate power, not only for profit, but mainly to ensure the continuity of operations and security of the organization (Miroński, 2007).

When analyzing risk - or, more broadly, when undertaking risk management, attention should be paid to the need to distinguish the concept of risk from uncertainty. In his considerations, Hubbard pointed out that uncertainty is related to the lack of complete certainty. It can be defined as the existence of more than one possibility and the outcomes and/or states, effects/values are unknown. Differently- Risk is also a state of uncertainty - however, due to the effects that may be associated with a specific loss, disaster or other undesirable outcomes, risk measurement will allow for the identification of a set of possibilities, where each eventuality has a calculated probability and size of losses (this is related to the probability distribution) (Hubbard, 2011). Therefore, the authors believe that risk should be considered a recognized and measured uncertainty.

Referring to the company's activities, the closest thing to its daily, ongoing activities is operational risk. It also allows you to determine to what extent the company is prepared organizationally and materially to achieve its goals (Zawiła-Niedźwiecki, 2010, pp. 153-154). Importantly, it should be remembered that when managing risk, one takes into account threats that may turn into disruptions and should mainly be analyzed in terms of not whether they will occur, but when.

However, the interaction of different levels of management (and its phases) seems to be important, most often resulting in events visible at the level of everyday, ongoing activity, hence the need to separate the concept of organizational risk (Stasiuk-Piekarska, 2017). By undertaking the process of organizing resource allocation and composing the workload, one strives to achieve the goals of the production system. However, this is related to many factors that should be treated as a generator of possible disruptions. As the rapidly changing reality has shown in recent years, in order to achieve the intended effects (or complete the assigned tasks), it is necessary to take actions to counteract disruptions or eliminate their effects in the operation of the production system. Hence the assumption that organizational risk is often associated with delays in the production system, as deficiencies in the praxological features of the organized whole. The described concept of organizational risk is related to the creation of: structures enabling the delegation of tasks, authorizations and responsibilities, as well as the preparation of processes (also in the context of the achievements of work methods, time related to labor intensity, durability and timeliness, as well as space and information for management). It is also related to the existence of threats and disruptions that result from the lack of coordination of the operation of elements and/or functionality, optimality, harmony and synergy of the entire system. It is assumed that organizational risk can be expressed as "the product of the frequency, the dimension of consequences and the probability of occurrence of a negative event related to the rationalization of demand and composing resources necessary to produce the final product". It should also be emphasized that it is concurrent with operational risk and involves establishing basic dependencies regarding the current (short-term) activity of the production system in space and time. When analyzing the causes of failures, errors and disruptions, it is recognized that some of them will be the result of improper assignment of tasks or improperly created processes. They will occur as a result of lack of coordination in the production system. Therefore, organizational risk is related to the occurrence of disruptions related to the rationalization of demand and the composition of resources necessary to produce the final product, and additionally it is a factor that in some way reflects the operation of the production system. Organizational risk, as mentioned previously, applies to all levels of system functioning, being a broader concept than operational risk (Stasiuk-Piekarska, 2017). These considerations are presented in Figure 2.

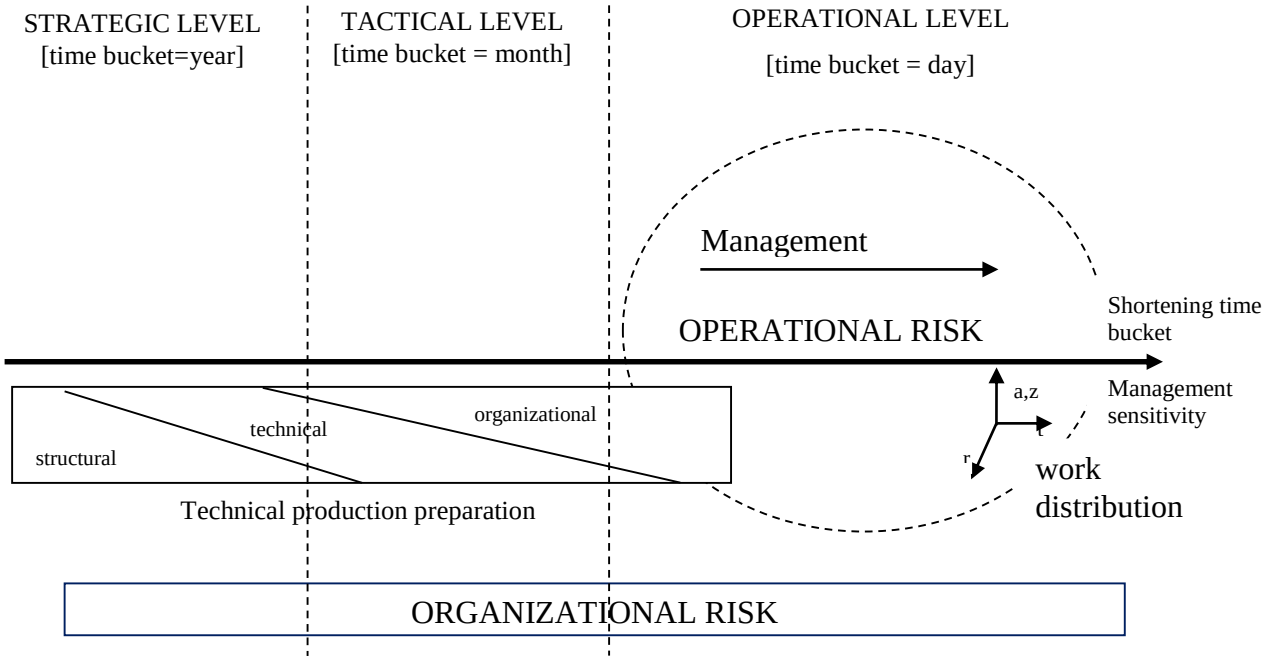

Figure 2. Organizational risk in the operation of the production system.

Source: Stasiuk-Piekarska, 2017, p. 86.

As shown in the figure, organizational risk is also related to the technical preparation of production as well as management sensitivities. Its conditions arise at the strategic and tactical level, but its existence is authenticated at the operational level. Similarly, the situation regarding macroergonomics, which mainly concerns the lowest level of management, but is created by all its levels.

Risk is also a state of uncertainty - however, due to the effects that may be associated with a specific loss, disaster or other undesirable outcomes, risk measurement will allow for the identification of a set of possibilities, where each eventuality has a calculated probability and size of losses (this is related to the probability distribution) (Hubbard, 2011). Therefore, the authors believe that risk should be considered a recognized and measured uncertainty.

Referring to the company's activities, the closest thing to its daily, ongoing activities is operational risk. It also allows you to determine to what extent the company is prepared organizationally and materially to achieve its goals (Zawiła-Niedźwiecki, 2010). Importantly, it should be remembered that when managing risk, one takes into account threats that may turn into disruptions and should mainly be analyzed in terms of not whether they will occur, but when. We should also not forget about the increasingly stronger impact of the ideas of sustainable development and occupational health and safety, which emphasize taking into account the role of the human employee in the production system (Pačaiová et al., 2024).

4. Macroergonomic influence factors in the context of organizational risk

To analyze the impact of factors of influence between macroergonomics and organizational risk, a scheme was created covering the connections of the above-mentioned spheres with each other. It should be emphasized that the previously mentioned work system, which is the production system, should be considered as a sociotechnical system. It includes the technology used in the organization, the human resources system, and the external environment. From the point of view of macroergonomics, technology - as an element determining the structure of the work system - can be analyzed according to:

- production method or production technology,
- actions that individuals take in relation to an object in order to change it, or to a knowledge-based technology,
- degree of automation.

The description of the above elements allows for the creation of the main model defining the relationship between technology and organizational design (Jasiak, 2016). In manufacturing enterprises, where a strong interaction between technology, organization and the human factor is identified, Computer-Integrated Manufacturing, Organization and People (CIMOP) may be helpful, serving for the IT integration of the above areas for design purposes (Karwoski, Kantola, Rodric, 2002). This method allows for support in cognitive processes in the field of change management in the work environment, among others: assessing the effectiveness of changes through simpler identification of problems, motivation to implement changes or description of the work system model (Mrugalska, Sławińska, 2014).

Looking for factors that link macroergonomics and organizational risk, the authors decided to use a simplified map of network thinking. The network thinking map was developed on the basis of the network thinking methodology (more: Piekarczyk, Zimniewicz, 2010). It is presented in Figure 3.

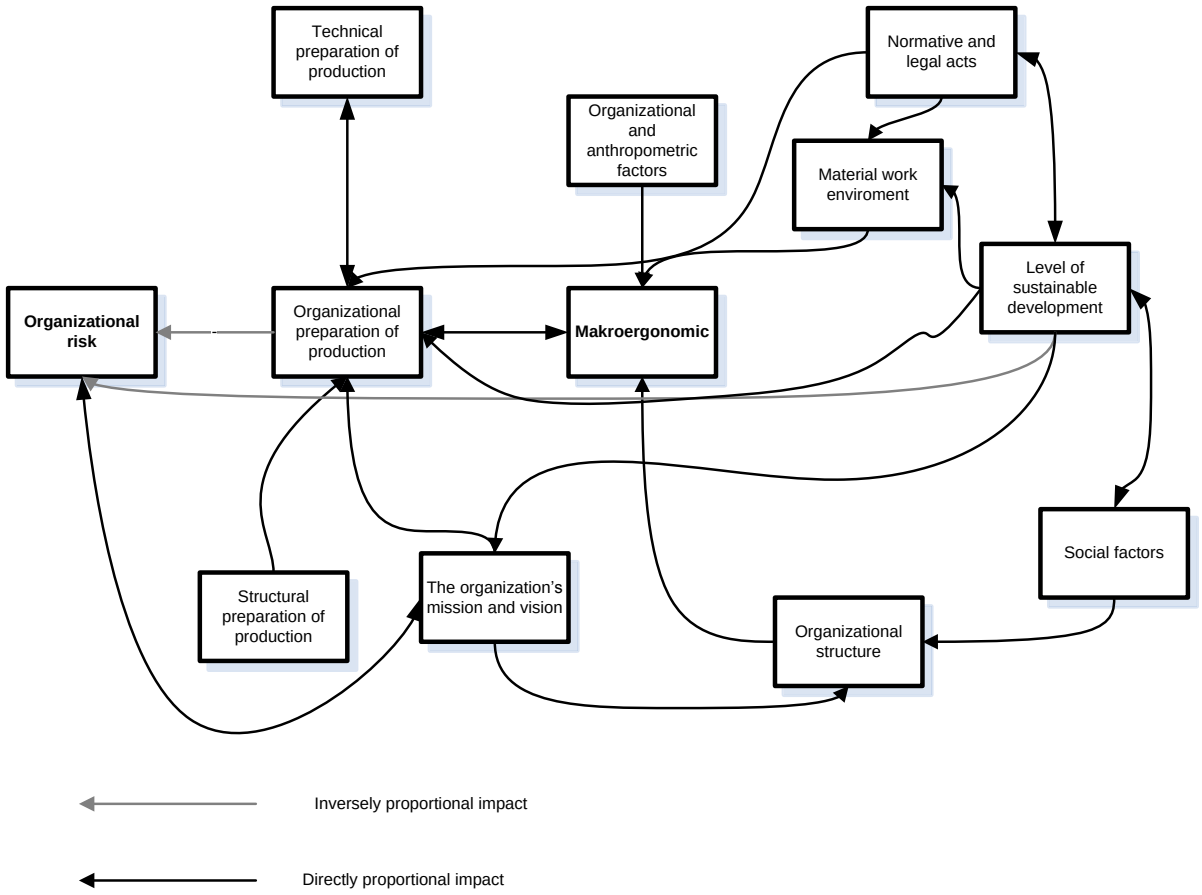

Figure 3. Preliminary analysis of the connections between macroergonomics and organizational risk. Source: own study.

Analyzing the connections between the factors, 12 factors were identified, deliberately omitting those related to the adopted business strategy, industry or size of the organization, as elements that translate into the mission and vision of the organization, technical, construction and organizational preparation of production. It was assumed that the impact may be directly proportional (black arrow) or inversely proportional (gray arrow), unidirectional or bidirectional. Since this is a preliminary analysis, not all elements and connections can be included, but it should be noted that an important element subject to frequent influence is the organizational preparation of production. At the same time, when analyzing the influences, the level of sustainable development seems to be an often influencing element - as a factor that is strongly supported by international standards and legal acts. Both of the above-mentioned factors have an inversely proportional impact on organizational risk (the higher the level of sustainable development, the lower the level of organizational risk, also the higher the level of organizational production preparation, the lower the level of organizational risk). At the same time, the impact of the organization's vision and mission should be emphasized - it can be assumed that proactive organizational risk management will have a positive impact on the decisions that will be made in setting the course of action for the entire organization. Conversely, the way and conscious (or less conscious) setting of the mission and vision in the

company may influence the level of organizational risk. When drawing conclusions about macroergonomics, we can also note that its level depends on many factors, however, it was assumed that the main connection and possibility of influencing organizational risk is the factor related to organizing the production process (which is, in a sense, a catalyst for other factors in the analyzed issue).

5. Summary

In the context of current activities aimed at structuring ISO management standards and the resulting need to manage risk (understood both as opportunities and threats - according to the principle that unused opportunities take revenge), as well as legal solutions leading to the implementation of the ESG standard in the field of sustainable activities, it is noted that not only risk management is important, but also care for the employee's well-being.

Macroergonomics is a field that studies various types of interactions between an employee and the entire organizational context for the purpose of creating a work environment that will promote employee health, productivity and satisfaction. By analyzing organizational structures, organizational culture, decision-making processes and other elements, it can have a positive impact on reducing the level of organizational risk. This is done by improving interpersonal relations, taking into account organizational aspects at all levels of management, with particular emphasis on the operational level, as well as improving the economic aspects of processes. It is assumed that conscious influence on both spheres can reduce the number of errors in implemented processes, which may ultimately translate into a higher degree of competitiveness of enterprises.

Acknowledgements

Article financed by the Faculty of Engineering Management of the Poznań University of Technology (SBAD 0811/SBAD/1056 and SBAD 0811/SBAD/1085).

References

1. Bertalanffy, L. (1984). *Ogólna teoria systemów*. Warszawa: PWN.
2. Bochenek, M. (ed.) (2012). Ryzyko i niepewność w naukach ekonomicznych − rozważania semantyczne. *Ekonomia [Economics], 4(21).* Wrocław: University of Economics Wrocław, pp. 64-63
3. Dragun, Ł. *Ergonomia stanowisk produkcyjnych- konieczność czy fanaberia.* Retrieved from: https://tqmsoft.com/ergonomia-stanowisk-produkcyjnych-koniecznosc-czy-fanaberia, 20.01.2024.
4. Faccio, M., Granata, I., Menini, A. et al. (2023). Human factors in cobot era: a review of modern production systems features. *J. Intell. Manuf., 34,* 85-106. https://doi.org/10.1007/s10845-022-01953-w
5. Fertsch, M., Pawlak, N., Stachowiak, A. (2011). *Współczesne systemy produkcyjne*. Poznań: Publishing House of the Poznań University of Technology.
6. Hendrick, H.W. (1987). Macroergonomics. A concept whose time has come. *Human Factors Society Bulletin, 30, 2, 4.*
7. Hendrick, H.W., Kleiner, B.M. (2001). *Macroergonomics. An introduction to work system design, Santa Monica.* Human Factors and Ergonomics Society Bulletin.
8. Hubbard, D.W. (2011). *Pomiar uniwersalny. Odkrywania w biznesie wartości niematerialnych.* Warszawa: MT Biznes.
9. Jasiak, A. (1993). Kryterium czynnika ludzkiego w projektowaniu systemów wytwarzania. *Rozprawa PP, no. 283.* Poznań.
10. Jasiak, A. (2016). Czwarte oblicze makroergonomii. *Zeszyty Naukowe Politechniki Poznańskiej, No. 71, Organizacja i Zarządzanie.* DOI: 10.21008/j.0239-9415.2016.071.13
11. Jasiak, A., Misztal, A. (2004). *Makroergonomia i projektowanie makroergonomiczne Materiały pomocnicze*. Poznań: Publishing House of the Poznań University of Technology.
12. Józefowska, J., http://www.cs.put.poznan.pl/jjozefowska/wyklady/swiz/opbw2.pdf, 28.12.2012.
13. Karwowski, W., Kantola, J., Rodrick, D. (2002). Macroergonomic Aspects of Manufacturing. In: H.W. Hendrick, B.M. Kleiner (eds.), *Macroergonomics, Theory, Methods, and Applications, Human Factors and Ergonomics* (pp. 223-247).
14. Kawecka-Endler, A. (2004). *Organizacja technicznego przygotowania produkcji - prac rozwojowych.* Poznań: Publishing House of the Poznań University of Technology.
15. Kleiner, B.M. (2006). Macroergonomics: Analysis and design of work systems. *Applied Ergonomics, Vol. 37, Iss. 1,* pp. 81-89, ISSN 0003-6870, https://doi.org/10.1016/j.apergo.2005.07.006.
16. Klimczak, K.M. (2008). Ryzyko w teorii ekonomii. *Master of Business Administration, 6,* pp. 64-69.

17. Lis, S. (ed.) (1982). *Rytmiczność procesu produkcyjnego. Zakłócenia i ich kompensacja*, Warszawa: PWE.
18. Mazurczak, J. (2002). *Projektowanie struktur systemów produkcyjnych*. Poznań: Publishing House of the Poznań University of Technology.
19. Miroński, J. (2007). Problematyka władzy w teorii ekonomii. *Gospodarka Narodowa, No. 4*, pp. 15-32.
20. Mrugalska, B., Sławińska, M. (2014). Narzędzia makroergonomii w sterowaniu bezpieczeństwem procesów pracy. *Zeszyty Naukowe Politechniki Poznańskiej, No. 63, Organizacja i Zarządzanie*.
21. Pačaiová, H., Turisová, R., Glatz, J., Onofrejová, D. (2024). Sustainability Assessment of Machinery Safety in a Manufacturing Organization Using AHP and CART Methods. *Sustainability, 16(9),* 3718. https://doi.org/10.3390/su16093718
22. Piekarczyk, A., Zimniewicz, K. (2010). *Myślenie sieciowe w teorii i praktyce*. Warszawa: PWE.
23. Rzeszotarska-Wyrwicka, M. (1998). *Organizowanie systemów pracy. Materiały pomocnicze*. Poznań: Publishing House of the Poznań University of Technology.
24. Senger, Z. (1998). *Sterowanie przepływem produkcji*. Poznań: Publishing House of the Poznań University of Technology.
25. Stasiuk, A., Werner, K. (2012). Production flow control as a key element in production management. In: Ł. Hadaś (ed.), *Produkction management - Contemporary approaches-selected aspects* (pp. 179-188). Poznań: Publishing House of the Poznań University of Technology.
26. Stasiuk-Piekarska, A.K. (2017). *Metodyka zarządzania ryzykiem organizacyjnym w systemach produkcyjnych* (Doctoral dissertation or Master's thesis). Poznań: Poznań University of Technology, Faculty of Engineering Management.
27. Stasiuk-Piekarska, A.K., Wyrwicka, M.K., Hadaś, Ł. (2020). *Ryzyko organizacyjne w produkcji*. Poznań: Publishing House of the Poznań University of Technology, Doi:10.21008/b.978-83-7775-614-0
28. Tian, F., Xin Xu, S. (2015). How do enterprise resource planning systems affect firm risk? Post-implementation impact. *MIS Quarterly, Vol. 39, No. 1/March*, pp. 39-60.
29. Wyrwicka, M.K. (2003). *Endogenne przesłanki organizacyjne rozwoju przedsiębiorstwa*. Poznań: Publishing House of the Poznań University of Technology.
30. Zawiła-Niedźwiecki, J. (2010). Ryzyko i bezpieczeństwo operacyjne. In: J. Monkiewicz, L. Gąsiorkiewicz (eds.), *Zarządzanie ryzykiem działalności organizacji* (pp. 153-168). Warszawa: C.H. Beck.