Jurnal Sistem Teknik Industri (JSTI) Vol. 25, No. 1, 2023 | 56 –64

JSTI
Jurnal Sistem Teknik Industri

Macro ergonomic Analysis and Design for Optimizing the Work Environment: A Literature Review

Suci Ayu Lestari[1], Listiani Nurul Huda[2], and Rosnani Ginting[3]

[1,2,3] Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara, Jl. Dr. T. Mansur No.9, Padang Bulan, Medan, Sumatera Utara, 20155, Indonesia

Abstract. The purpose of this literature is to understand the application of macro ergonomics in various fields. Macro ergonomics is the study of work systems which include organizational structures (complexity, formalization, centralization, policies, and processes) with a socio-technical approach used to improve work systems. The method used is a thematic analysis of articles on the application of macro ergonomics in various industries. Based on the results of the article review, the process of implementing macro ergonomics is analysis, design, implementation, control, and evaluation. All review articles carry out macro ergonomics analysis and design within the scope of the work system as a whole but do not intervene in all factors/problems. The reviewed articles show that the intervention is carried out only on a few factors, where human and organizational factors are always involved. The application of macro ergonomics can achieve many goals at once that are beneficial to organizations, workers, and even consumers. The highest frequency of macro ergonomics objectives in consecutive review articles was: quality, occupational health, safety, work existence, productivity, efficiency, and effectiveness.

Keyword: Macro ergonomic, Analysis, Design, Implementation, Work System

Abstrak. *Tujuan literatur ini untuk memahami penerapan ergonomi makro di berbagai bidang. Ergonomi makro adalah ilmu yang mempelajari sistem kerja yang meliputi struktur organisasi (kompleksitas, formalisasi, sentralisasi, kebijakan, dan proses) dengan pendekatan sosio-teknis yang digunakan untuk memperbaiki sistem kerja. Metode yang digunakan adalah analisis tematik artikel tentang penerapan ergonomi makro di berbagai industri. Berdasarkan hasil review artikel, proses penerapan ergonomi makro adalah analisis, desain, implementasi, kontrol dan evaluasi. Semua artikel review melakukan analisis dan desain ergonomi makro dalam lingkup sistem kerja secara keseluruhan, tetapi tidak mengintervensi keseluruhan faktor/masalah. Artikel yang diulas menunjukkan bahwa intervensi dilakukan hanya pada beberapa faktor, di mana faktor manusia dan organisasi selalu terlibat. Penerapan ergonomi makro dapat mencapai banyak tujuan sekaligus yang bermanfaat bagi organisasi, pekerja, bahkan konsumen. Frekuensi tertinggi tujuan ergonomi makro dalam artikel ulasan berturut-turut adalah: kualitas, kesehatan kerja, keselamatan, keberadaan kerja, produktivitas, efisiensi, dan efektvitas.*

Kata Kunci: Ergonomi Makro, Analisis, Desain, Implemantasi, Sistem Kerja

Received 29 July 2022 | Revised 05 September 2022 | Accepted 11 December 2022

*Corresponding author at: [Universitas Sumatera Utara, Jl. Dr. T. Mansur No.9, Medan, 20155, Indonesia]
E-mail address: [suciayu5555@gmail.com]

p-ISSN: 1411-5247 | e-ISSN: 2527-9408 | DOI 10.32734/jsti.v25i1.9286
Journal Homepage: https://talenta.usu.ac.id/jsti

1. Introduction

Every organization needs to set up a unified work system to operate and achieve its goals. Ergonomics can be defined as the study of work [1]. Improving the overall system properly and overall performance is the final last goal of ergonomics which is finished thru ergonomic interventions. The definition of the intervention approaches deliberate motion via humans to create trade. Those interventions can be applied at the micro and macro stages of ergonomics in companies' groups, industries, places of work, discipline research, and so forth [2].

The application of ergonomics aims to improve people's capabilities, competencies, consolation, and overall performance [3]. Micro ergonomic adapts work at the individual level in analyzing specific tasks, while macro ergonomic adapts organizations to humans to improve work system performance [4]. Macro ergonomic is the examination of work systems and specializes in achieving a harmonious work system [5]. Experience in the industry shows that macro ergonomics is a critical and powerful component in creating an appropriate place of work [6].

Macro ergonomic is needed to facilitate management's understanding of aligning human factors with company strategy to improve effective performance [7]. The potential of macro ergonomics as a feasible implementation strategy by discussing the human aspect, machine technology, and the surrounding environment to seek optimization [8]. The main goal of macro ergonomic is to ensure that the whole work system is harmonious and matches its sociotechnical character, providing synergistic improvements to the organization, such as health, comfort, safety, and productivity [9][10].

The motive of this paper is to review the literature on macro ergonomic analysis and design based on the collected references regarding its development and application to optimize the work environment.

2. Macro Ergonomic

Macro ergonomic is a branch of science that Hal W. Hendrick first introduced in 1980. This branch of ergonomics emerged due to the rapid development of technology, exceeding the speed of organizational development, but also due to weaknesses in micro ergonomic. How nicely an operating system is designed will decide how powerful the work system might be [11]. The macro ergonomic approach system is also related to the quality of worker health and safety [12].

Table 1 Comparison of Micro ergonomic and Macro ergonomic (Kleiner Brian M [11])

Characteristics	Micro ergonomic	Macro ergonomic
Language Level	Micro	Macro
Work unit	Tasks, sub-tasks	Division of work, group
Destination	Optimize work	Optimize work system
Focus	Details	Extensive review
Measurement Tool	Generally measuring bodily together with place, illuminance, decibels, and time	commonly organizational and measures subjectivity includes the range of human beings, a span of management, conduct, and morals
Skills Application	Anatomy, psychology, psychology of belief	Organizational conduct, industrial psychology, and organizations

Macro ergonomic is incorporated as it includes knowledge, methods, and tools from socio-technical structure, business psychology, structural design, physical ergonomics, and theoretical ergonomics. As a technology, macro ergonomic directs the development of an understanding of work structures, conduct, or employees that engage with hardware or software programs inside the internal physical environment, outside environment, and organizational structures and approaches to become higher [13].

3. Macro Ergonomic Factors And Elements

Macro ergonomic is the study of work systems [14], including organizational structure (complexity, formalization, centralization), policies, and processes with a socio-technical approach. Figure 1 suggests the framework of macro ergonomic. The work system includes people who together (i.e., personnel subsystem) perform work (i.e., task subsystem) and interact with technology (i.e., technology subsystem) in an organizational system characterized by an environment (both physical and cultural) [11].

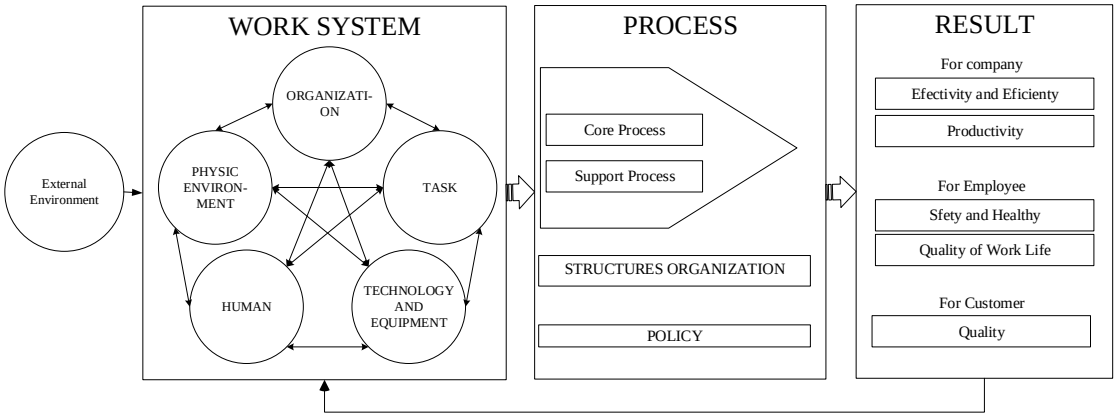

Figure 1 Macro Ergonomics Framework

In macro ergonomic, these subsystems are named as factors in macro ergonomic, which will be analyzed to improve work systems. Table 2 contains macro ergonomic factors and elements. These factors have interdependent characteristics so that changes in one can affect the other [15]. The design of factors concerning each other determines how effective the work system is [16].

Table 2 Macro Ergonomic Factors and Elements

Factor	Element
Person	Training, abilities, and expertise Professional level Demographics Motivation and desires Physical traits Psychological traits
Organization	Work of the team Coherence, collaboration, and verbal exchange Schedule of working Social relative Control and supervision mode Performance assessment, reward, and additional income

Factor	Element
Technology and equipment	Data Technology Manufacturing generation development Traits of human factors on technology and equipment (usability).
Task	Type of work Activity content, challenges, and skill usage Autonomy, work management, and participation Work needs (workload, time strain, cognitive load, need for attention)
Physical environment	Layout, Noise, lighting fixtures, temperature Workstation design.
External environment	Political Culture Socio-economic Education Regulation

Macro ergonomic emphasizes the interaction between (1) the psychosocial and organizational context of the system; with (2) the design, execution, and application of technology in a system [13][14]. Improvement of the structure and process of the work system may be executed by using a) analysis and design of the general structure and process of the work system and then running operation thru the subsystems and elements, or vice versa, b) factor analysis then systematically building the structure and process of the whole system [10].

The process of applying macro ergonomics is iterative, nonlinear, and stochastic. Through macro ergonomic literature, the stages of implementing macro ergonomic are summarized, especially (1) analysis of work systems or problems with one of the factors in the work system; (2) designing improvements; (3) implementation of improvements in the whole work system or intervention on one factor; (4) control and evaluation of work system performance.

The main goal of macro ergonomic is to ensure the general work system is harmonious and matches its sociotechnical character, providing synergistic improvements to the organization such as health, comfort, safety, and productivity [9][10]. The results of macro ergonomic are not only on optimal and effective functioning systems, but also productivity, safety, comfort, and quality of work life because the system design is human-oriented [5].

4. Implementation of Macro Ergonomic Analysis and Design

According to W. Hendrick and Brian M. Kleiner, the implementation of macro ergonomic consists of ten stages called the Macro Ergonomic Analysis and Design (MEAD) technique [13]. MEAD is a method such as of several stages used to enhance work systems [17]. This method is related to designing, analyzing, and evaluating work systems in organizations so that they become effective and efficient [18]

1. Analyzing the organization, specifically checking/scanning the system,
2. Define the form of the production system and set the desired stage of overall performance.
3. Defining unit operations and work processes
4. Identify variances

5. Create a variance matrix
6. Create variance control and personnel function analysis
7. Allocating functions and combining designs
8. Analyze stakeholder perceptions and duties
9. Redesign help and merge subsystems
10. System Repair

5. Research Method

The technique used in this paper is a literature review observation. The writing of this literature review is primarily based on international and national journals. To obtain research objectives, The research process is divided into three stages, especially: 1) Searching and selecting literature according to the criteria, 2) Classification of literature based on the applied industry and the involvement of ergonomic macro factors, and 3) Analyzing thematically selected articles.

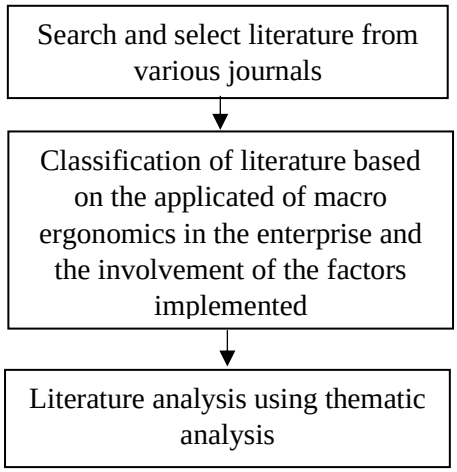

Figure 2 Research Stages

This study aims to conduct an in-depth understanding of macro ergonomic and the development of its application in research. A search is done on database google School, Science Direct, Taylor & Francis, Emerald, JMIR, and Wiley Online Library. Searches were performed using keywords such as “Macro ergonomics” and “Macro ergonomic Analysis and Design.” The criteria in the search were articles discussing the application of macro ergonomics, originating from journals ranked by Scimago and Sinta.

6. Results

6.1. General Results

Macro ergonomics is considered to assist companies in increasing competitiveness. The application of macro ergonomics can be found in various industries, including the service industry, manufacturing, and office environments. Based on the results of the article review, about 45% of the articles show the application of macro ergonomics in the service industry, such as unit services in hospitals and education; 40% of the articles cover the application of macro ergonomics in manufacturing industries, such as the automotive industry, wood processing, tile and ceramic

factories, and others; and 15% of the articles contain the application of macro ergonomics in management in an office environment. Interestingly, there were articles regarding applications in the service industry every year. This may indicate a high interest in macro ergonomics in the service industry.

Table 3 Frequency of Application of Macro ergonomics in Industry

Application of Macro ergonomics	Publication
Service Industry	Heidarimoghadam, et al [2], Carayon [4], Carayon, et al [12], El-Bahey & Zeib [17], Suzianti, et al [18], Okta, et al [23], Debastiani, et al [25]
Manufacture	Realyvásquez, et al [5], Taghipour, et al [6], Pradini, et al [19], Kurniawan, et al [21], Sari,et al [22], Azadeh, et al [24]
Office Environment	Village, et al [7], Dominingues, et al [8]

Based on the article review results, all analysis and design were carried out using a top-down macro ergonomic approach within the scope of the work system. The most frequently considered macro ergonomic factors were people, organization, technology, environment, and tasks, by 21%, 21%, 21%, 19%, 18%.

Table 4 Frequency of Factor Involvement in the Application of Macro ergonomics in Industry

Article	Publication
Person	Heidarimoghadam, et al [2], Realyvásquez, et al [5], Taghipour, et al [6], Carayon, et al [12], Bahey & Zeib [17], Suzianti, et al [18], Kurniawan et al [21], Sari,et al [22], Okta, et al [23], Azadeh, et al [24], Debastiani, et al [25]
Organization	Heidarimoghadam, et al [2], Carayon [4], Realyvásquez, et al [5], Taghipour, et al [6], Carayon, et al [12], Bahey & Zeib [17], Suzianti, et al [18], Pradini, et al [19] Sari,et al [22], Okta, et al [23], Debastiani, et al [25]
Technology and Equipment	Carayon [4] Realyvásquez, et al [5] Taghipour, et al [6], Carayon, et al [12], Bahey & Zeib [17], Pradini, et al [19], Kurniawan, et al [21], Sari,et al [22], Okta, et al [23], Azadeh, et al [24], Debastiani, et al [25]
Task	Heidarimoghadam, et al [2] Carayon [4] Realyvásquez, et al [5] Taghipour, et al [6], Carayon, et al [12], Bahey & Zeib [17], Sari,et al [22], Okta, et al [23], Azadeh, et al [24]
Environment	Heidarimoghadam, et al [2] Taghipour, et al [6], Carayon, et al [12], Bahey & Zeib [17], Suzianti, et al [18], Kurniawan, et al [21], Sari,et al [22], Okta, et al [23], Azadeh, et al [24], Debastiani, et al [25]

6.2. Thematic Analysis

Pradinirch, et al [19] made improvements to the work system with the Macro ergonomic Analysis And Design (MEAD) approach to increase worker productivity in the shipbuilding industry. The research was conducted by considering physical environmental, equipment/machinery, working conditions, and organizational factors. Analysis and processing of data from measuring workers' pulse and resting energy consumption obtained additional rest time to increase productivity in the measurement and cutting of the ship's wood components.

Kurniawan, et al [21] researched to observe the effect the work environment has on the capacity of workers in UD. Ulin Putra with multiple linear regression studies and system studies that utilize macro ergonomics. In the study of systems with a macro ergonomic approach, there are

difficulties of balance in the work environment as a result, restoration of the management system requires the contribution of labor for preventive action in the work environment, and technology systems need a little funding in conjunction with building turbine ventilators, for environment systems, it is necessary to reorganize the workspace.

Sari, et al [22] researched to improve the circumstance of the physical work environment with a macro ergonomics approach using simulation with the help of Powersim software. Macro ergonomics has succeeded in increasing work productivity in producing briquette fuel from coconut shells, from 293 products to 302 products in line with the increase in the company's profit.

Okta, et al [23] established a potential hazard assessment in the industry with a macro ergonomic approach using the IDEACM stages. Ergonomics and OSH experts analyze potential hazards with a macro approach assessment framework and define IDEACM stages that may be utilized in all manufacturing and carrier industries.

Azadeh, et al [24] applied IRE and macro ergonomics approaches to improve the safety and capability of complicated factory systems, which include tile or ceramic factories. This study intends to decide the optimal conceptual approach with integrated macro ergonomics and integrated strength engineering. This research showed that integrating IRE with macro ergonomics factors increases the system's accuracy.

Debastiani, et al [25] conducted a macro ergonomic study within the sewing laboratory of an undergraduate program to discover Ergonomic Demand with an activity macro ergonomics by considering the individual aspects of the activities carried out in this workspace. The macro ergonomic was found to be effective in identifying ergonomic requirements, assisting in assessing and providing recommendations for sewing laboratory reconstruction, increasing performance and efficiency, and improving the health and well-being of everyone using this workspace.

Macro ergonomics is considered to assist companies in increasing competitiveness. Based on the review of the article, it was found that macro ergonomics has been applied in various industries, including the service industry, manufacturing, and office environment. The interesting thing found in reviewing the literature is the application of macro ergonomics within the carrier industry every year. This can indicate a high interest in macro ergonomics in the service industry, especially in the health sector.

The macro ergonomics factors that are most often considered from the results of a successive literature review are people, organization, technology, environment, and tasks. The scope of performance criteria that can be achieved from applying macro ergonomics is very broad.

Based on the review article, the most performance criteria are quality, occupational health, safety, work existence, productivity, efficiency, and effectiveness.

7. Conclusion

Improving the overall system properly and overall performance is the final goal of ergonomics which is performed through ergonomic interventions. Through searching from various sources, presenting a brief overview of the application of macro ergonomics analysis and design in various industries. Research with macro ergonomics is in maximum demand within the health industries. Applying macro ergonomics is analysis, design, implementation, control, and evaluation. All research on the application of macro ergonomics in the last 10 years has analyzed and designed macro ergonomics processes within the scope of the work system but did not intervene on all factors/problems. The articles reviewed show that the intervention is carried out on only a few factors, where human and organizational factors are always involved.

The application of macro ergonomics can achieve many goals at once that are beneficial for organizations, workers, and even consumers. The highest frequency goals for implementing macro ergonomics are quality, quality, occupational health, safety, work existence, productivity, efficiency, and effectiveness. Intervening in all factors in macro ergonomics, especially equipment, and integrated with analysis of work environment factors and the risk of harm, it is beneficial for organizations, workers, and even consumers, especially in the health sector. The ultimate goal is to optimize the work environment, which includes health and safety, along with improving the quality of work life, efficiency, and effectiveness of the work system.

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