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RETHINKING THE CONDITION OF ERGONOMICS FOR SUSTAINABLE DEVELOPMENT

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Abstract: *The significance of sustainable development has increased in last years, being addressed in an interdisciplinary way. Sustainability and ergonomics could be easy linked because of their common wellbeing vision for human systems (social or professional). Integrating sustainability with ergonomics, could create important opportunities for researchers and practitioners to capture attention and promote new working conditions. Thus, companies are becoming more and more involved in the social responsibility projects related to workplace wellbeing or sustainable development workplaces. This paper aims to investigate the ergonomic conditions that must be included in the sustainable development approach. The methodology used includes the use of the Delphi technique by involving one facilitator and 40 experts from the manufacturing field, evaluating the literature and the empirical experience. At the end of the paper are presented the conditions of ergonomics related to the considered five phases of product life cycle (the phases are: pre-manufacturing, manufacturing, use, post-use and re-manufacturing), in the context of the circular economy. Future research is aimed at extending this framework to other industries.*
Key words: *Sustainability, ergonomic, sustainable workplace, social responsibility, ergonomics-based Factors health and safety.*

1. INTRODUCTION

Although initially the sustainable development aimed, first, an ecological perspective, later it expanded on the social and economic aspects. Development based on economic growth remained until the 1970s, when it was obvious that both consumerism and economic growth put pressure on the environment with the consequences of polluted and inadequate living space, poverty and disease [8]. At the same time, the exploitation of natural resources, especially the stock of fossil fuels and raw materials, has led to the deliberation of the needs of future generations and has created a prerequisite for defining the attitude of long-term and rational use of limited natural resources [3; 19; 20]. The imbalance between human development and ecological boundaries has highlighted the increase of environmental problems and possible consequences with disastrous proportions [5; 6]. The causes of environmental pollution can be: a) anthropic causes of environmental pollution (economic growth, technical and technological development, industrial development, development of traffic and transport infrastructure, population growth, urbanization and mass tourism); b) natural causes of environmental pollution (soil erosion, floods, earthquakes, volcano eruptions, fires, droughts and wind); c) other causes of environmental pollution (wars, the imbalance between development and natural ecosystems and the limited scientific, material, organizational and technological opportunities of the society). The consequences of these factors are present in various ecological problems, disturbances of the ecosystem, global climate change, natural disasters, hunger and poverty and many other negative consequences [4; 8; 12; 18].

Developed country initiatives to help improve the socio-economic and environmental situations of developing and underdeveloped countries gathered scientists, economists and humanists from ten countries, in Rome, in 1968

to discuss current issues and future challenges of humanity (limited natural resources, population growth, economic development, ecological problems and others) [11]. Grouped as an independent global organization called the Rome Club, these scientists have published two significant editions - Limits of Growth in 1972 and Mankind at the Turning Point in 1974, which contain research findings and motivate the population to change their behavior towards the planet [21; 22]. The Rome Club has warned that excessive industrialization and economic development will soon cross the borders of ecology. In 1971, Nicolae Georgescu-Roegen published The Entropy Law and the Economic Process, similarly warning of the dangers of economic development and marking the beginning of the ecological economy and the environmental economy [8;13].

Different organizations and institutions participated in the creation of the concept of sustainable development. The most significant is the United Nations (UN), founded in 1945, with headquarters in New York (UN, 2015), which today includes 193 member states. Its main objectives include maintaining peace and security in the world, promoting sustainable development, protecting human rights and fundamental freedoms, promoting international law, suppressing poverty and promoting tolerance and cooperation [2; 3; 4; 7; 8].

Sustainable development was defined by the United Nations Brundtland Commission in the year. The triple bottom line includes three *dimensions* that need to be evaluated at the organizational level: economic, social and environmental [8;23].

By evaluating the history and evolution [2; 3; 4; 6; 7; 11; 12; 24] of the concept of sustainable development, we can outline fundamental principles, as follows:

- Ensuring the needs and care of the community of present and future generations,
- Continuous improvement of the overall quality of life and equality,
- Protecting and conserving the environment, biodiversity and ecosystems,
- *Identification and improvement of human characteristics*,
- *Improving the jobs and designing the equipment, designing and organizing the work, the health and safety of the employees,*
- Changing production and consumption while respecting ecological constraints, using renewable energy and innovative technologies to reduce the negative impact on the environment,
- Intensifying international, national, regional and local cooperation, creating an institutional framework with a strong network of stakeholders attracted by the implementation of the concept of sustainable development.

Many of the principles outlined above are frequently researched in *ergonomics*. These principles are directly associated with *social responsibility* and with implications in the economic and environmental dimensions.

The paper aims to investigate the ergonomic conditions that must be included in the approach to sustainable development in the processing industry.

2. ERGONOMICS AND SUSTAINABILITY

2.1 Implications and connections

The goods are produced in manufacturing processes that have direct and indirect interactions with the company, as a whole (employees, company owners, community and customers) [17]. This interaction can be observed throughout their life cycles, being present in reverse logistics. Therefore, the evaluation of the power of ergonomics is important for the efficiency of the impacts of the products on the company [7]. Disciplines such as sustainability, engineering, design, manufacturing, logistics and ergonomics are important pillars in this efficiency [17; 18; 19].

The field of ergonomics plays an important role in making the transition to sustainable development, because both ergonomics and sustainable development are human centered [1; 2; 3; 4]. Ergonomics evaluates human factors and is concerned with an understanding of the interactions between humans and other elements of a production system.

In the specialized literature, the clear contributions to the organizational transition

from ergonomics to sustainable development are missing, which leads to the idea that few researchers consider ergonomics and sustainability in improving organizational efficiency [5]. Ergonomics contributes to the improvement of sustainability dimensions should be considered in the development of strategic actions [6; 7].

2.2 Sustainable Manufacturing

Products manufactured by industries must have optimized negative and positive impacts on society, the environment and the economy [13]. At the same time, in keeping with the current evolution, the development of sustainable products is being pursued. These sustainable products are considered to have an efficient impact on society, the environment and the economy. Sustainable manufacturing of products is a key issue for achieving sustainable development [8; 10; 19].

The main elements of the sustainable manufacturing are presented in Figure 1. The following are considered: energy consumption, waste management, operational safety, and personnel health [8; 9]. Each direction [14; 15; 16] has factors related to ergonomics, as follows:

- Energy consumption - working conditions, relationships, environment;
- Waste management - working conditions, relationships, environment;
- Operational safety - working conditions, workplaces, workload;
- Personnel health - Sustainable workplaces, relationships, population, human characteristics.

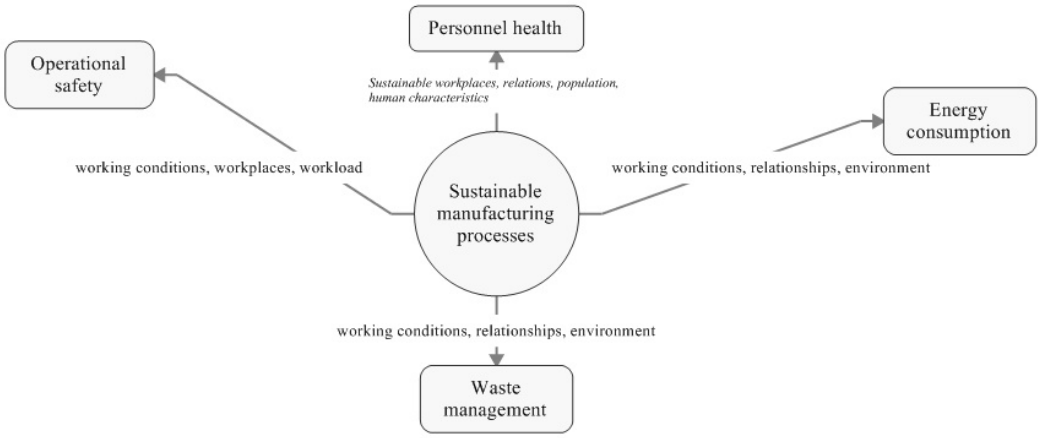

Fig. 1. Sustainable manufacturing processes

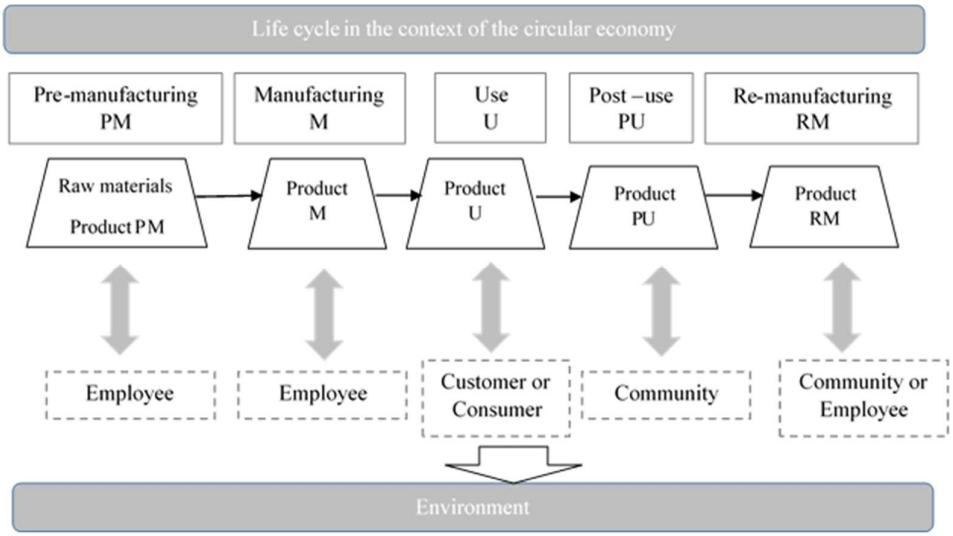

Fig. 2. Relationships between pre-manufacturing (PM), manufacturing (M), use (U), post-use (PU) and re-manufacturing (RM) and customer, consumer, community or employee

The five phases of the life cycle in the context of the circular economy: pre-manufacturing (PM), manufacturing (M), use (U), post-use (PU) and re-manufacturing (RM) are shown in Figure 2. It can be observed that for each stage the relation with the human relations (client, consumer, community or employee) is specified. It can be observed that in the PM stage the employee intervenes, in the M stage the employees intervene, in the U stage the customers or consumers intervene, in the PU stage the community intervenes because the implications of the product reach the community, and when the product is no longer used it should it returns to the manufacturing process as a raw material.

Sustainable development and ergonomics evaluate the efficiency of the activities of the industries within the three economic, social and environmental dimensions. An attempt is being made to identify the conditions of ergonomics that contribute to the sustainability of the industries. For this evaluation, the five stages presented must be considered.

3. RESEARCH METHODOLOGY

The research methodology consists of Delphi method involving one facilitator and 40 experts from the manufacturing, evaluating the literature and empirical experience.

The Delphi method is a process and forecast framework that is based on the different rounds of questions that are sent to an expert group of individuals. Expert groups provide the answers anonymously. The reports are gathered in reports of the working rounds. There is a report for each round. These reports are shared with the entire group after the end of each round. If the report is not accepted by all experts, a new round of questions and discussions will take place. When the report is accepted, that report is the final one [10; 11; 12].

This research in the automotive industry has been comprehensive in several directions. For this work, the ergonomic direction of the research carried out is used.

For the research, a facilitator from the automotive industry was identified. This facilitator is the manager of a Department of processes and research and development. The main features of the facilitator are the experience of over 30 years in manufacturing, the manager of a company with over 3,000 employees, significant results in sustainable development evidenced in the efficiency of processes and jobs, good communicator with all organizational levels. The automotive industry has an important manufacturing segment in Romania. The facilitator works with an expert group consisting of 40 experts. Experts activate in the six segments of manufacturing industry, as follows:

- Automotive (15 experts);
- Production of foams, chemicals, plastics, oil (7 experts);
- Food and beverage production (5 experts);
- Furniture production (5 experts);
- Pharmaceutical production (4 experts);
- Other productions (metal, electronic, non-metallic, clothing) (4 experts).

The research targeted several directions and elements investigated. These are presented in Table 1. From these areas and directions, the results were selected which refer to ergonomics and sustainability (see Table 2).

Table 1

Directions and elements investigated.

Direction	Investigated Elements
Company information	Field of activity: Identification of the best-selling product Number of Employees Assessment of the level of innovation of the company (0-100)
Interpretation, facilitators and barriers	Identification of company practices in industry 4.0 Evaluation of industry facilitators 4.0 Barriers industry 4.0
Maturity	Identifying the degree of maturity Evaluation of a proposed model for digital maturity that includes strategy, technology, operations, organization and culture and clients.
National Technology Platform Industry 4.0	Evaluation of the national platform industry 4.0 Assessment of the importance of the actors of the industry 4.0 platform: government, universities and research institutes, users-companies of industry 4.0 and suppliers of industry 4.0 The level of resistance to digitization Transforming the company into the digitalization era

Table 2

Ergonomic conditions for the sustainable development of manufacturing.

Life cycle stage	Economic dimension	Social dimension	Environmental dimension
PM	• Product Safety • Product Reliability • Physical effort of the post • Social support • Personal development of the worker • Independence at work • Work-related concerns • The difficulty or complexity of the tasks • Risk of accident, Risk of illness, Risk of redundancy	• Workplace Accidents • Physical Workload • Physiological Workload • Psychological Workload • Organizational Workload • Working Conditions • Security of the system • Workplace Safety • Defective tools, equipment, or supplies	• Material Utilization • Material Quality • Climate of the working environment • Hazardous atmospheric condition • Poor ventilation • Excessive noise • Congestion in the workplace
M	Same conditions as for PM	Same conditions as for PM	Same conditions as for PM
U	• Product Serviceability • Product Quality • Product Usability • User Satisfaction • User Experience	• Customer/stakeholders condition • Security of the product • The conditions of the communication relationship with the company	• Impact of the product on the consumer or client • Product packaging • The degree of difficulty of the instructions
PU	• Product safety for the community • Product security • Social support	• The conditions of the communication relationship with the company	• Impact of the product on the environment • The action of the packaging on the environment
RM	• Product Safety • Product Reliability • Physical effort of the post • Social support • Personal development of the worker • Independence at work • Work-related concerns • The difficulty or complexity of the tasks • Risk of accident, Risk of illness, Risk of redundancy • Reverse logistics conditions	• Workplace Accidents • Physical Workload • Physiological Workload • Psychological Workload • Organizational Workload • Working Conditions • Security of the system • Workplace Safety • Defective tools, equipment, or supplies • Communication within the material recovery processes	• Liquid Particulate Emission • Solid Particulate Emission • The level of remanufacturing • Reverse logistics • Climate of the working environment • Hazardous atmospheric condition • Poor ventilation • Excessive noise • Congestion in the workplace • Impact of the raw materials on the environment

The specialized literature presents a series of results in the two fields: ergonomics and sustainability. The report provided after the Delphi analysis was updated based on the literature and empirical experience of the authors. The authors' experience is emphasized mainly by research in the field, as follows: Sustainable Development Model for the Automotive Industry based on in-depth interviews with 33 experts (published in the Sustainability Journal).

Integrating Sustainability and Lean: SLIM Method and Enterprise Game Proposed - To train students as sustainability and lean experts (published in Sustainability Journal), Occupational Accident Assessment by Field of Activity and Investigation Model for Prevention and Control - Identifying risks and proposing preventive and corrective measures in the direction of sustainable development (published in Safety Journal), Risk Indicators and Road Accident Analysis for the Period 2012 – 2016 - Strategic framework for the sustainability of transport (published in Sustainability Journal), The Evaluation and Application of the TRIZ Method for Increasing Eco-Innovative Levels in SMEs - Furniture production was tested (published in Sustainability Journal), and Sustainable Development and Technological Impact on CO_2 Reducing Conditions in Romania

- CO_2 reduction for improving climatic conditions (published in Sustainability Journal).

The results obtained were evaluated by manufacturing experts. At the end of the paper are presented the conditions of ergonomics on the 5 phases of the life cycle in the context of the circular economy (pre-manufacturing, manufacturing, use, post-use and re-manufacturing).

4. RESULTS AND DISCUSSIONS

The results obtained from the research carried out are presented in Table 2. It can be observed that for each stage provided for the analysis, the conditions related to the three dimensions of sustainability were identified.

Following the research carried out, a series of ergonomic conditions have been obtained for sustainable development. The results obtained can be found in the final report of the experts. This report is a complex one, from which some data were extracted for this research. The final report was obtained in round 3 of discussions. It can be observed in Table 2 that these conditions are presented on the five stages of the life cycle in the context of the circular economy. The conditions are aimed at employers, customers, consumers, and community. Depending on the evaluated stage, the conditions based on the entity involved in the activity of production, use, post-use or remanufacturing are presented.

For example, for the first stage, pre-manufacturing, the conditions of the economic dimension to be evaluated for the sustainable manufacturing are: product safety, product reliability, physical effort of the post, social support, personal development of the worker, independence at work, work-related concerns, difficulty or complexity of the tasks, risk of accident, risk of illness, and risk of redundancy. The conditions of the social dimension that must be evaluated for sustainable manufacturing are workplace accidents, physical workload, physiological workload, psychological workload, organizational workload, working conditions, system security, workplace safety, and defective tools, equipment, or supplies. The conditions of the environmental dimension to be evaluated for sustainable manufacturing are material utilization, quality material, climate of the working environment, hazardous atmospheric condition, poor ventilation, excessive noise, and congestion in the workplace.

This framework for evaluating manufacturing conditions can be extended to other areas as well. In addition, future studies will be developed in a collaborative and innovative manner as mention in [25; 26;27].

5. CONCLUSION

Sustainability and ergonomics are important for increasing the competitiveness of companies. This study conducted a research with manufacturing experts to identify ergonomic conditions that contribute to manufacturing sustainability. In round 3 of the research, the report comprising the interpretations of the experts was made. These experts were coordinated by a facilitator with extensive experience in the automotive field. The results can be extended to other areas as well. These results are part of a comprehensive research conducted in 2019.

Sustainability is an approach appreciated by more and more companies, and the involvement of companies is increasing (over 95%) from 100 companies surveyed replied that they know the concept and fully implement it. The intensification of the activities has been realized since the last years, because of the actions of the stakeholders.

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Regândirea condițiilor ergonomice pentru dezvoltare sustenabilă

Rezumat: Semnificația dezvoltării sustenabile a crescut în ultimii ani, aceasta fiind abordată într-o manieră interdisciplinară. Sustenabilitatea și ergonomia ar putea fi ușor conectate datorită viziunii lor comune privind bunăstarea în sistemele umane (sociale sau profesionale). Integrarea sustenabilității cu ergonomia ar putea crea oportunități importante pentru cercetători și practicieni pentru a capta atenția și a promova locuri de muncă sustenabile. Astfel, companiile devin din ce în ce mai implicate în proiecte de responsabilitate socială legate de bunăstarea la locul de muncă sau dezvoltarea de locuri de muncă sustenabile. Acest articol își propune să investigheze aspectele ergonomice ce trebuie considerate în abordări realizate din perspectiva dezvoltării sustenabile. Metodologia folosită include utilizarea tehnicii Delphi prin implicarea unui facilitator și a 40 de experți din domeniul fabricație, dar și pe baza evaluării literaturii și a experienței empirice. La finalul lucrării sunt prezentate aspectele ergonomice identificate aferent celor cinci faze ale ciclului de viață ale produsului (pre-fabricație, fabricație, utilizare, post-utilizare și re-fabricație), în contextul economiei circulare. Cercetările viitoare vizează extinderea aplicării acestui cadru pentru alte industrii.

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