Politehnica University of Timisoara
PhD field *Engineering and Management*

# EVALUATION OF ERGNOMICS INTERVENTION IN PRODUCTION SYSTEMS

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**PhD Thesis – Summary, March 2022**

## 1. Summary of the PhD Thesis

The current socio-economic environment is characterised by dynamism, technological innovations and social and economic changes that occur in short timeframes. In the economic field the great challenge is to acquire the capacity of fast and successful adaptation to changes, which involve – among others – compliance with numerous norms and standards regarding quality and occupational health and safety (OHS). Moreover, competitivity and long-term success of a business and conditioned by its sustainability initiatives, ergonomics being a vehicle to achieve the company's strategic objectives.

At organizational level, compliance with current legislation is not sufficient, as it represents the minimal operational level from the ergonomics perspective. Employee wellbeing is one of the sustainability strategy targets, achievable through conception of ergonomics interventions for optimisation of working conditions and improvement of work satisfaction. From this point of view, the importance of ergonomics becomes vital for meeting productivity, efficiency, and efficacy objectives of the company. This is due to the interdisciplinary character of ergonomics – a science covering knowledge and expertise in fields such as engineering, design, medicine, psychology, management, or economics. Understood as a process of optimizing the activity of organizations (starting from tasks and work equipment and ending with the achievement of sustainability, efficiency, and effectiveness objectives), ergonomic intervention is necessary to ensure a harmonious and safe working environment, but also to create products and services in accordance with the needs and particularities of the human body.

The lightning speed of the technological evolution in the last decades has determined changes in the way companies operate, creating new jobs as well as new risks of injury and illness at work. This is one of the reasons why EU occupational health and safety statistics show that ergonomic risks remain at the forefront of the most common occupational hazards, despite the concerted efforts of all parties involved.

At national level, a major gap in the implementation of ergonomics principles in the current activity of organizations lies in the absence of normative acts regulating the need to comply with these principles in the design of jobs. Reference is made here both to the way work is organized and to the means of work, machines and equipment used. Given that the central element of ergonomics is the human being, ergonomic interventions aim to optimize jobs or the execution of work tasks in such a way that the purpose of these interventions is to improve the professional life quality.

The design and implementation of an ergonomic intervention depends on the objectives pursued by the intervention, but also on the tools and working methods used. However, there is a discrepancy between the perspectives of researchers and practitioners on the design of ergonomic interventions: what researchers consider to be optimized differs from the actual expectations and needs of practitioners. From this point of view, it is necessary to harmonize

expectations with the practice of ergonomics by creating a working methodology (ergonomic intervention toolkit) that is easy to implement in organizations. Also, this toolkit must meet the need for continuous improvement, so *it is imperative to design an ergonomic intervention toolkit that allows the evaluation and continuous improvement of the work system*. This is the research gap, which refers to the design of an ergonomic intervention methodology aimed at covering the evaluation of the work system, the correction of identified risks and organizational deficiencies, the economic and financial substantiation of corrective measures, implementation of proposed measures and re-evaluation to optimize the whole process.

In this context, the research topic aims to answer the question: *How to evaluate the authenticity of ergonomic intervention in work systems to analyse its performance (in terms of effectiveness, efficiency, and relevance) to help increase the quality of professional life*? To answer this question, the author defined the following operational objectives of the research theme:

- **OP1** Description of the conceptual framework, respectively the approach of work systems from the perspective of ergonomics and the minimization of occupational risks and accidents at work
- **OP2** Theoretical substantiation of the approach to evaluate the intervention of ergonomics in work systems
- **OP3** Proposing a theoretical-applicative approach on ergonomics intervention in work systems
- **OP4** Modelling and implementation of an innovative model of ergonomic intervention in work systems to reduce occupational risks
- **OP5** Testing and validation of the proposed innovative model

Consequently, ***the general objective of the research topic is to develop an innovative model of ergonomic intervention in work systems, focused on the principles of participatory ergonomics and continuous improvement***. The main aim of this model is to include the development and capitalization of an interdisciplinary team of specialists in the process of optimizing the organization's activity from the perspective of its efficiency, effectiveness, and relevance.

Interest in this research topic is closely linked to the day-to-day challenges of organizations, as they increasingly face productivity issues, compliance with OHS standards and legislation, workers' dissatisfaction with high exposure to ergonomic risks and physical work environment-related risks. A reality of Romanian companies is the lack of know-how in the field of ergonomics, the economic environment in Romania being deeply marked by the very small number of experienced ergonomists who support the design and implementation of ergonomic interventions. Thus, the research carried out during the doctoral program was intended to create a methodological framework that is easy to implement, which would facilitate the development of a proactive attitude in identifying risks and optimizing jobs.

The approach followed to achieve the general objective and operational objectives is presented in Figure 0.1. A thorough study of the bibliographic resources and applied studies on ergonomics interventions was carried out to identify relevant working methods and tools, but also to observe the shortcomings of the proposals of other researchers. These theoretical studies served to develop a theoretical-applicative model for the implementation of ergonomics interventions, the model being validated through applied research conducted at two companies. Finally, the decisions on the proposed ergonomic interventions were analysed economically and financially.

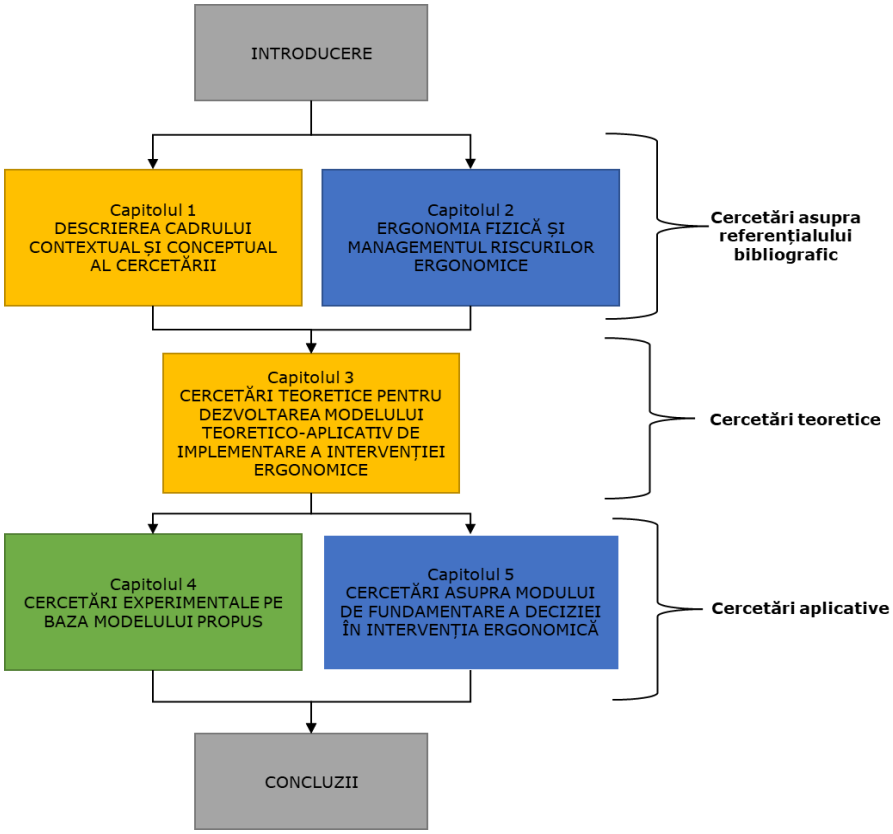


*Figure 1 PhD thesis logical structure (flow chart)*

**Chapter 1,** entitled **"Description of the contextual and conceptual framework of research"** analyses the national and international level of manifestation of ergonomics. The legislation and standards in the field of OHS were analysed, as well as the reports and studies prepared by the European Agency for Safety and Health at Work, to understand the degree of penetration of ergonomics in the current activity of companies. Also, the first chapter captures theoretical concepts regarding the quality of professional life and the role played by ergonomics in supporting the quality of professional life.

**Chapter 2,** with the title **"Physical ergonomics and ergonomic risks management"**, summarizes the conclusions derived from the study of bibliographic references on physical ergonomics, professional risks ontology and ergonomic risks management. This chapter refers to concepts such as OHS, biomechanics and kinesiology, and methods for ergonomic risks assessment. A noteworthy aspect is that in Chapter 2 a synthesis of the software tools used for the assessment and management of ergonomic risks was made, revealing the way in which the technological evolution was put in the service of ergonomics.

**Chapter 3,** entitled **"Theoretical research for the development of the theoretical-applicative model for the implementation of ergonomics intervention"**, describes the proposed methodological approach for the conception and implementation of ergonomics interventions. It is a frontier chapter, which substantiates the methodological framework for conducting applied research. The theoretical-applicative model of ergonomics intervention, described in subchapter 3.5, is based on:

a. Description of human-machine-environment system (subchapter 3.1);
b. Detailed study of legislation, national and international standards applicable to physical work environment: noise, illumination, microclimate, and indoor air quality (subchapter 3.2);
c. Description of ergonomic risks assessments using an Artificial Intelligence software (subchapter 3.3);

d. Work system analysis using RNUR method (subchapter 3.4).

**Chapter 4, "Experimental research based on the proposed model",** describes how the applied research was carried out based on the theoretical-applicative model proposed in Chapter 3. The experimental studies were carried out in two companies operating in Timiș County. This chapter presents (for the two companies) the results of measurements of physical work environment parameters (performed with the support of the Laboratory of Fuel Analysis, Ecological Investigations and Dispersion), ergonomic risks analysis with the ergoIA software and work system analysis using the RNUR method. This chapter also presents proposed corrective action to address deviations from existing legislation and the principles of ergonomics.

**Chapter 5,** entitled **"Research on how to corroborate the decision in ergonomics intervention",** has as a starting point the corrective intervention measures proposed for the jobs analysed in the case of the two companies and presents a methodology for validation of decisions on ergonomic interventions from an economic-financial point of view. Thus, the proposed ergonomics interventions were analysed using the global utility method and cost-benefit analysis to generate a hierarchy of implementation for these interventions. Finally, Chapter 5 presents an analysis of the maturity model of ergonomics in the two companies.

Finally, **Chapter 6**, named **"Conclusions, personal contributions and future research directions",** presents the methodological results of doctoral research, highlights personal contributions in the field of theoretical and practical research on ergonomics interventions and provides an overview of future research directions derived from the results of the doctoral program.

## 2. Overview of the Conclusions and the Main Research Findings

### (1) Review of Bibliographic Research (Chapters 1 and 2)

- At national level, the manifestation framework of ergonomics as a field of research and profession was marked by a significant impetus given by the introduction of the ergonomist profession in the Occupational Classification in Romania and the development of the associated occupational standard (in 2017), and the establishment, in 2019, of the Ergonomics & Workplace Management Society (ErgoWork).
- Compliance with the rules and principles of ergonomics at work is not mandatory in Romania, the national legislation being limited to imposing minimum requirements on OHS. Consequently, there is an acute lack of ergonomic practice within organizations, with statistical data indicating a high incidence of occupational diseases and injuries at work.
- EU-OSHA has distinguished itself through its constant efforts to centralize the main issues faced by EU companies and through information and awareness campaigns on the importance of ergonomics and OHS. It should be noted that in 2019 EU-OSHA conducted the third edition of the European Survey of Enterprises on New and Emerging Risks (ESENER), which is a valuable barometer of the evolution of ergonomics in the EU.
- The small-scale implementation of ergonomics in the current activity of organizations has led, along with other factors, to the placement of Romania on the last place in the EU in the Social Progress Index (with a score of 78.41 / 100), proving that there are major gaps in generating the social and professional well-being of Romanians. In this context, the concept of quality of professional life becomes an important dimension to be quantified both at the social level and at the level of organizational performance.
- The bibliographic study on the role of ergonomics in ensuring the quality of professional life led to the conclusion that, although insufficiently studied, ergonomic interventions aimed at increasing the professional well-being of workers proved to bring real benefits to companies that decided to implement them. Thus, implementation of ergonomic

interventions increases the productivity and efficiency of the work system, while generating benefits with reverberations in the organizational culture and market value of the company.

- Research on the negative effects of occupational MSDs indicates a reduction in workers' quality of life by limiting work capacity and reducing healthy life expectancy. The onset of the Covid-19 pandemic, through health restrictions imposed to reduce the spread of the disease, has deepened the problem.
- Although MSDs are multifactorial disorders, there is evidence in the literature on the link between the strain of biomechanical factors in the workplace and the diagnosis of work-related MSDs.
- The main types of postural stresses that can lead to acute or chronic forms of MSDs are work in difficult conditions, repetitive hand and arm movements, static work, and sedentary work. MSDs are the second most reported category of occupational diseases in the EU, after cancer.
- For the efficient management of ergonomic risks (defined as the category of risks generating MSDs), it is necessary to understand the mechanisms of pain production and overload of a bone lever, these processes being described in detail in subchapter 2.3.
- There are various approaches to limiting the occurrence of MSDs in the workplace, the most important being education and awareness programs, alternating positions and micropauses, postural rehabilitation and the introduction of equipment and tools to compensate for lost work capacity with the onset of symptoms associated with MSDs. In terms of rehabilitation, this can be done (depending on the severity of the situation) through medical rehabilitation, vocational rehabilitation, and social rehabilitation.
- From the multitude of methods and means of ergonomic risks assessment, the main investigative methods established in ergonomics practice were presented: CERA, the Standardized Nordic Questionnaire, the NIOSH method, OCRA, OWAS, REBA, ROSA and Total Worker Health programs. Given the rapid technological evolution, it was considered necessary to make an inventory of software tools for ergonomic risks assessment, some of which use technologies such as artificial intelligence.

**(2) Doctoral Research Methodological Review**

As a result of the research carried out, a methodological framework is presented demonstrating the usefulness of the research and the easy transfer in the practice of the organizations. This methodological framework is based on an analytical approach consisting of three major steps:

I. The investigation stage of the work system based on the methodology proposed in Chapter 3, consisting of the on-site visit for the preliminary discussion with the managers, shift managers and the OHS manager, but also for understanding the research context through the observation method. This is followed by a second visit to perform measurements of noise, lighting, microclimate, and dust, as well as video recordings of how the work is performed (to analyse the ergonomic risks);

II. The design stage of the ergonomic interventions, having as starting point the analysis of the data collected during the visits to the targeted workplaces. This stage consists of the processing and interpretation of measurements on the physical work environment, the analysis of ergonomic risks using the ergoIA software and a general analysis of jobs with the RNUR method. Based on the results obtained, corrective intervention measures are proposed, aimed at reducing the identified risks and optimizing jobs.

III. Economic-financial (using the global utility method and cost-benefit analysis) and strategic substantiation of the proposed ergonomic interventions (using the tool for ergonomic maturity model proposed by Mocan (2020)).


*Figure 2 Ergonomics Intervention Model (EIM)*

Figure 2 schematically shows the Ergonomic Intervention Model (EIM), which is the result of the steps presented above. The whole approach is based on OHS legislation, national and international standards regarding assessment of the physical environment parameters, as well as guidelines, procedures, and internal standards on ergonomics. Their synthesis is made in Chapter 3. The EIM is a general conclusion of the doctoral research, the model being a validated and generally applicable tool for the design and implementation of ergonomics interventions, regardless of the organization's size or the complexity of the jobs analysed.

The design of the EIM is in line with the NIOSH principles of the Participatory Ergonomics Toolkit for Total Worker Health. In fact, there are several elements common to the two methodologies, as both generate reverberations in the organizational culture by involving all parties affected by the implementation of that ergonomic intervention, as well as by interdisciplinary collaborations for the design of ergonomics interventions. Thus, EIM is not an audit or assessment tool for the risks of occupational injuries or illnesses but is a set of methods and means of collecting and interpreting various categories of information, all put at the service of correcting and optimizing the work system to ensure the highest possible level professional life quality.

An OHS audit, whether it involves a job or the entire organization, aims at an objective and documented analysis of the situation at a given time and compliance with applicable norms and standards (Darabont et al., 2002). Moraru (2016) shows that the application of OHS standards does not ensure the integration of OHS and ergonomics in decision-making processes, and the implementation of a management system does not necessarily create a culture of OHS. EIM differs from an OHS audit by its integrative and broad approach, the aim being to create the premises for the development of an organizational strategy on ergonomics and to support the achievement of the associated objectives throughout this complex process. It should be noted that EIM is geared towards continuous system improvement, being a model that supports the dynamic analysis of the work system.

**(3) Conclusions of the Applicative Research (Chapters 4 and 5)**

EIM was validated by covering the three steps for workplace analysis in two companies operating in Timiș county.

In the case of Company A, which operates in the ergonomic furniture industry, the risks identified were exposure to noise (especially noise shocks), dust emissions in large quantities,

manual material handling and awkward positions (trunk twisting, bending). It was concluded that the company was compliant with existing OHS legislation, but legislative gaps have allowed for certain risks that are problematic in terms of long-term exposure (years). Considering the absence of a proactive / preventive approach to risks, the premises for design of major ergonomic interventions, with long-term implementation, in addition to those related to the correction of identified deficiencies, were outlined. From an economic and financial point of view, most of the proposed interventions have an investment return ratio larger than 1, so they are justified for implementation from all points of view.

Regarding Company B, which provides waste management services in the western part of the country, the analysis referred to the recyclable waste sorting hall of the ecological landfill G. It was found that there is a wide variety of risks to which operators are exposed, including deviations from the national OHS legislation. Thus, urgent ergonomic interventions have been designed to address problems such as: exposure to noise levels that significantly exceed the maximum exposure value of 85 dB, the risk of injury from deformed containers falling from a high height (from the lifting system) or the presence of bumps and ditches in the floor on the route of manual handling of containers loaded with PET bottles (risk of tripping, overload of the osteo-articular system during handling). Also, standardization interventions (medium-term implementation) and ergonomic interventions aimed at re-designing the workplace were proposed. Since some of the proposed ergonomic interventions involve large investments, the return-on-investment ration did not justify them economically. However, it should not be overlooked that in the case of ergonomic interventions, the return-on-investment ratio is not an argument in the decision not to implement that intervention, the benefits often resulting in effects that cannot be quantified in monetary terms.

In conclusion, the EIM was used to identify deviations from the legislation on the physical work environment risks (noise, inadequate lighting, dust emissions above the maximum permitted limits), postural strains to which operators are exposed during execution of work tasks, but also the shortcomings of organising work. Consequently, it was possible to formulate corrective and optimization measures for the various problems identified, which were investment options subject to the last stage of the EIM. Thus, the variants of ergonomic interventions were analysed for the economic-financial substantiation of the decision on the optimal ergonomics intervention. Finally, the maturity level of the ergonomics strategy in the two companies was analysed.

## 3. The Original Contributions of the Research

During the doctoral program, research on the bibliographic references, theoretical research and applicative research generated numerous personal contributions, as follows:

1. **Personal contributions in the field of research on the bibliographic references (reflected by content of Chapters 1 and 2)**
    a. Mapping the level of manifestation of the science and practice of ergonomics in the Romanian space and at EU level, as well as revealing the main contributors to this evolution.
    b. Motivated definition of the major role that ergonomics plays in achieving workers' quality of life goals and the implications of the Covid-19 pandemic for deteriorating well-being at work.
    c. Synthesis of the connections between physical ergonomics and professional risks, through conceptual developments and logical argumentation of the implications of ergonomic risks on the performance of the work system.

d. Development and argumentation from the perspective of interdisciplinarity of ergonomic risks management. From the concepts of biomechanics and physiology to notions of recovery medicine, subchapter 2.3 provides a comprehensive approach to the genesis and management of ergonomic risks and MSDs.
e. Inventory of methods and means of investigating ergonomic risks, to facilitate the understanding of practitioners' perspective on ergonomic risks management.
f. **Premiere in synthesis of modern instruments for ergonomic risks assessment**, starting from the idea that ergonomic practice is increasingly based on innovative means of workplace design and ergonomic risks assessment. Thus, subchapter 2.4. presents various software tools that allow not only the assessment of ergonomic risks, but also simulations that support the conception of ergonomics interventions with high efficiency in implementation.
g. Identification of the research gap starting from the conclusions drawn from the study of the bibliographic references. Therefore, although there is a significant number of theoretical and applied research on ergonomic interventions in the scientific literature, they are characterized by methodologies limited to certain categories of risks or specific professions. There is a major gap in the design of comprehensive and versatile methodologies of ergonomics interventions.

**2. Personal contributions to theoretical research (as presented in Chapter 3)**

- Inventory of methods and means of investigating the risks specific to the physical work environment, finalized by proposing a methodology for investigating the parameters of the physical work environment.
- Description of how to assess ergonomic risks using state-of-the-art software based on artificial intelligence.
- **Creative methodological developments, the theoretical-applicative model proposed for ergonomic intervention being the result of innovation by combination**.

**3. Personal contributions to applicative research (as described in Chapters 4 and 5)**

- Carrying out *in situ* research within two companies operating in different industries, validating the proposed theoretical-applicative model. The research was conducted during the Covid-19 pandemic, creating a unique research context considering the challenges posed by nationally imposed health restrictions.
- Interdisciplinary collaborations for conducting applied research, as follows:
    - Laboratory of Fuel Analysis, Ecological Investigations and Pollutants Dispersion for measurements of noise, lighting, microclimate, and airborne dust;
    - Biomechanical Institute of Valencia to use ergoIA software for ergonomic risks analysis;
    - Specialists in ergonomics and OHS fields to organise a focus group dedicated to validation of economic and financial analysis criterion.
- Validation of a complex methodology for conception and implementation of ergonomics interventions in manufacturing systems.

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