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Ergonomics in Business Logistics

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ERGONOMICS IN BUSINESS LOGISTICS

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ABSTRACT

The submitted monograph deals with the possibilities of ergonomics implementation in business logistics with the aim to provide sustainable competitiveness of enterprises via effective human work in ergonomically acceptable and flexible conditions. For the purposes of the current monograph, business logistics is studied on the level of logistic operations involving all employees who perform work activities directly initiating disorders and damages to the musculoskeletal system. The monograph analyses the methodology of ergonomics implementation in business logistics through the improvement of work activities and reducing employees' stress. In the above-mentioned methodology, an employee represents both, an object and a subject of all efforts building the work environment. This includes supporting the sustainable quality of employees' work life while simultaneously considering both environmental and economic conditions. The monograph focuses on the outcomes of the projects "*Transforming industry in Slovakia through participatory ergonomics No. 019/2001*" and is currently supported by the VEGA and KEGA grants (*VEGA – Transformation of ergonomic programme into the structure of company management via integration and utilisation of QMS, EMS and HSMS modules; KEGA – 037STU-4/2012: Introducing the subject of "Sustainable Corporate Social Responsibility" into the Master's degree study programme of Industrial Management at STU MTF Trnava*).

Key words

ergonomics, business logistics, sustainable development, kazien

SCIENTIFIC CONTRIBUTION

The current social situation makes people aware that the future is affected by their present actions, and it is therefore important to think about the trend of development. It primarily concerns management of the companies which may use this publication as a suitable "tool" of further self–development and ultimately the development of society.

The current monograph is to provide the managers and senior staff at all levels of management, as well as undergraduates and postgraduates of the engineering and possibly other interested universities with a comprehensive summary of information regarding the selected issues of application of ergonomics in the field of business logistics for the sustainable competitiveness of the Slovak industrial enterprises through efficient human work in the 21st century. The publication is highly topical in terms of both scientific research and practical utilisation since it focuses on the application of ergonomics in business logistics within the context of the recent global crisis while regarding the current state of economy and changes in the European and global environment.

The scientific contribution of the monograph dwells in the proposed methodology for the implementation of ergonomics in business logistics based on the accumulation of knowledge in the field of ergonomics and business logistics and the research conducted in selected industrial enterprises. The monograph applies a wide range of mathematical and statistical apparatus, which allowed obtaining relevant data and information and evaluating it statistically in order to generalise new scientific knowledge. The methodology was designed to facilitate the development of the working environment enabling employees the required long-term and stable work

performance while minimising the impact of risk factors on the occurrence of musculoskeletal system disorders due to the long–term excessive unilateral exposure. The submitted monograph also assesses the cost–benefits and rationalisation measures to ensure the required level of work efficiency.

The contribution of the monograph oriented on the application of methodology for ergonomics implementation in business logistics in the enterprises in the Slovak Republic is its anti-crisis potential. The monograph uses ergonomic knowledge and programs based on the principles of participatory ergonomics in business practice and a systematic approach to solving problems of the status of man in the working system.

INTRODUCTION

Social life is currently characterised by great dynamic changes influencing all society components and levels. Despite many pitfalls, the modern economy with advanced markets keeps developing. The economic development and increased demands for quality and quantity of the manufacturing and service processes is accompanied by the development of logistics. Continuous development forces us to adopt and use new working methods and procedures. On the threshold of the 21st century, logistics became an inevitable component of company strategic management. Logistic services are the source of competitiveness. It is therefore necessary to perceive logistics as a key component of strategic management rather than an executor of a marketing role for "delivering the right product to the right place at the right time and in the required quality".

The main human activities within business logistics are primarily material handling, the use of technology on different levels of mechanisation and automation (e.g. loading and unloading materials, local transportation, storage in warehouses, offices supplies and taking off the finished products or subassemblies) as well as mental work determined by activities and the related psychological burden. These activities, as well as many others, are performed at the intersection between business logistics and ergonomics. It should be noted that material handling which forms a part of the tasks and operations carried out within business logistics is a common cause of accidents and diseases and it ultimately affects the efficiency of human work and operations carried out.

Ergonomics focuses on the human work activity within the complex man-machine-working environment system. It is a scientific discipline

integrating the knowledge from bio-medical, psycho-social and technical-economic sciences. Ergonomics searches for the methods of adapting work to people with regards to their psycho-physiological capabilities through the application and integration of knowledge from all scientific disciplines. In doing so, the objective is to increase the effectiveness of human labour and cost benefit, and reduce negative impacts on human health. It therefore represents an important tool for the implementation of anti-crisis measures and for the creation of resources and best practices for sustainable industry development.

Ergonomics deals with the issues of the optimum design of work procedures, workplaces and tools, optimisation of the operating mode, human intervention in automated systems, as well as the optimum performance of employees through training and motivation. Through aligning all the requirements and creating harmonious working conditions the aim is to achieve the maximum working performance and employees' satisfaction.

The submitted monograph focuses on the results attained in the Slovak-American project "*Transforming industry in Slovakia trough participatory ergonomics No. 019/2001*". The project output was an HCS 3E model elaborating the principle of a targeted, long-term, comprehensive and synergistic process affecting the conditions and aspects (economic, environmental and social) of life on the local level (economic, environmental and ergonomic pillars).

This publication is simultaneously supported by the on-going KEGA and VEGA grant projects (VEGA - Transformation of an ergonomic programme into the structure of plant management via the integration and utilisation of QMS, EMS and HSMS modules; KEGA - 037STU-4/2012:

Introduction of the subject “Sustainable Corporate Social Responsibility” into the Master’s degree study programme of Industrial Management at STU MTF Trnava).

The author believes that the target orientation on the ergonomic aspect in creating harmonious working conditions may provide sustainable competitiveness of an enterprise through the effectiveness of human labour in the business logistics processes.

1. OUTCOMES OF ERGONOMICS IMPLEMENTATION IN BUSINESS LOGISTICS

At a time of constant changes and necessity to quickly adapt to varying customer demands, business logistics plays a significant role in the entrepreneurial activity of all companies. Since logistic processes such as transport and storage of final products do not add value to the final product, the businesses that are able to optimise logistics process gain the advantage. Competitive advantage is achieved by finding solutions to improved production flexibility, reduced delivery times, increased inventory turns, reduced capital bound in inventories, increased efficiency of handled materials and increased flexibility of the performed work activities. Manpower represents one of the key and simultaneously limiting factors influencing the effectiveness of the processes implemented in all areas of business logistics. Suitable working conditions and minimised risk factors can therefore help implement logistics solutions leading to increased labour efficiency, elimination of waste and leaning of logistics processes.

1.1 Definitions of ergonomics and logistics

The literature and professional publications comprise various definitions of ergonomics and logistics; some of them are listed below.

Ergonomics

In his book *Ergonómia* (Ergonomics) (1), Sablik defines ergonomics as an interdisciplinary scientific discipline based on the principles of human

work, which explores the options of adapting work to man and man to work with particular regard to man's psycho-physiological potential.

Attwood defines ergonomics as a systematic design process, in which people apply their knowledge to effectively use the equipment and improve the environment in which they work performing the tasks and operating the systems that govern the safe and efficient operations (2).

According to Cohen, ergonomics can be understood as the science of adapting the working environment and work demands to the skills of the working population. Effective and successful "adaptations" can guarantee the elimination of risks of diseases and injuries and simultaneously increase employees' satisfaction (3).

In their book *Kodak's Ergonomic Design for People at Work*, Chengular, Rodgers and Bernard define ergonomics as a multidisciplinary activity which seeks to gather information about human capabilities and skills in order to use this information in the work, products, workplaces and equipment design (4).

Following is the definition of ergonomics by the International Ergonomics Association (IEA) published in the year 2000: "*Ergonomics is a scientific discipline that focuses on defining and understanding interactions between humans and the rest of the work system, and also a profession that uses the theory, principles, data and methods designed to optimise the design of human wellbeing (health and prosperity)*".

Ergonomic activities contribute to the design and evaluation of tasks, products, environments and systems in order to make them compatible with the needs, skills and capabilities of employees (5, 6).

Individual authors describe ergonomics as a scientific discipline adapting the work conditions and working environment to a man. The definition of the International Ergonomics Association which captures the essence of modern comprehensive understanding of ergonomics in a developed society of the 21st century can be considered the most appropriate.

However, all the above-mentioned definitions lack the focus on the principle of sustainability and efficiency of the work operations performed by employees. This orientation should be an essential component of the ergonomics concept.

Logistics

The oldest and the best-known definition of logistics is that by the experts of the ***Council of Logistics Management – CLM***, an American logistics institution (7, 8, 9), that defined logistics as a term describing "the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption for the purposes of satisfying customer requirements".

H.CH. Pfohl (7, 10) characterises logistics as the total of all activities forming, managing and controlling the movement and accumulation processes in a given network. Harmonisation of these processes may provide a smooth flow of the objects in the network while using time and space in the most effective way.

JHDE, G. B. describes logistics as "a system of production, management, regulation and control over the material, energy and information flow and relocation of people".

Rose defines logistics as “a system of tangible and intangible chains consisting of the components which are interconnected by the material and information links: transportation, material handling, storage, packaging, geographical distribution, inventory check, documentation, information and services” (11).

According to ELA – the European Logistics Association, logistics means “organising, planning, managing and executing the flow of goods, starting with the development and purchase and ending with the production and shipment to the end customer, in order to meet all the market requirements at minimum cost and capital expenditure” (7, 8, 12, 13, 14, 15).

1.2 Goals, importance and benefits of ergonomics in business logistics

Ergonomics focuses on increasing the efficiency of human work. It has two basic objectives and indicators to assess the quality of solutions: a positive effect on the health of employees and an economic effect (16). Following are the parameters to evaluate the performance of employees’ output in the implementation of ergonomic solutions:

- *health*
- *safety*
- *work hygiene.*

The area of ergonomics research in the field of business logistics focuses on the issues of internal and external determinants of human performance. It explains the impact of work and the working environment on people through the physiological response of their bodies to the physical and

mental demands. It focuses on reducing fatigue and potential acute or chronic health disorders by means of such solutions that respect the possibilities as well as the hygienic, functional and psychological requirements of employees.

The aim is to find practical options of achieving a higher level of man's adaptation to his work, while regarding both human health and economic aspects (16). Therefore, success in terms of ergonomics can be a solution that brings the above-mentioned positive effect on the health of employees and a simultaneous economic benefit (16).

The application of ergonomic principles aimed at minimising the impact of labour and the working environment has a positive impact on economic indicators. These directly affect the reduction of the cost of sick leave and the litigation costs due to claims of employees for accidents, reducing also the costs associated with recruiting, income, job training and retraining of new employees and the production of scrap, damaged materials during handling, while assuring increased efficiency and hence growth of productivity.

It can be therefore concluded that the achieved economic effect is directly related to the health of employees.

The importance of ergonomics in the field of business logistics is placed mainly in the compliance of technical solutions and product features, and their adaptation to human capabilities and needs. The benefits are proven - from such an ordinary aspect as enjoying the work in a pleasant environment with easy-to-operate machines, up to the documentable increase of job performance or reduction of errors/defects (17).

Of particular importance is the anti-crisis potential of applying the knowledge of ergonomics and ergonomics programmes in business practice.

The application of ergonomics principles can lead to the following benefits (18):

- ***for a company*** – reduced staff sickness and diseases, increased work performance, increased work efficiency, reduced errors and defects, improved mental state of employees,
- ***for an employee*** – improved mental and physical conditions of employees, minimised symptoms of mental and physical fatigue, social benefits - higher job satisfaction, positive impact on the economic situation of individuals and families,
- ***for a society*** – improved health status of population, increased living standards of population, development of companies and entrepreneurial environment.

Besides properly designed work processes, facilities and jobs, the key benefits of ergonomics in the field of business logistics may be reflected in increased productivity, work safety, health and employee satisfaction. This can be achieved by applying various levels of technical tools, while reducing not only the physical load but also the psychological stress of employees, and thus achieving greater productivity and ultimately higher profitability. The interest in achieving greater productivity, higher job satisfaction and improved health of employees along with safety in the workplace increases the significance of ergonomics (4).

The major benefit of ergonomics in business logistics is that it comes with a systemic approach to the problems of a man within the system composed of a man and environment (19).

1.3 Ergonomic risks of a working process in the field of business logistics

While working, employees are exposed to a number of the interacting factors arising from the working environment and work activity, and causing so called combined effects. Individual factors (and their influence on man at work) may thus add up, multiply, reduce or even eliminate each other (17).

Generally, the above-mentioned factors can be classified as the physical, chemical, biological, psychological and socio-economic ones (20, 21). In terms of their impact on human health, they may be broadly classified as cumulative pathogenic, acute pathogenic, traumatogenic and terminal.

The ergonomic studies conducted in the field of business logistics should identify potential risk factors in the working process, which can be broadly categorised as (20):

- ***modifiable risk factors*** – their direct impact on the employee's health and performance can be modified by preventive measures. They can be further divided to:
  - physical (temperature, noise, vibrations, radiation, limited adaptability of workplace to the employee's body dimensions),
  - chemical (toxins, heavy metals, carcinogens),
  - biological (micro-organisms, plant and animal allergens),
  - psycho–social (unsuitable accommodation, aggression, low income, unemployment, stress),
  - manners and habits (smoking, alcoholism, drug addiction, increased consummation of animal fats),

- ***non-modifiable or personal risk factors*** – their direct impact on the employees' health and performance cannot be modified
  - age,
  - sex,
  - somatotype,
  - body dimensions.

In terms of ergonomics, the major active pathogenic cumulative risk factors that may occur in the conditions of business logistics comprise (22, 23):

1. Extreme or unnatural positions of joints

While working, it is recommended to keep the movements close to the middle range of the joints radius while minimising the unnatural positions such as twisting wrists to the sides or extreme flexion and extension. The gripping strength of fingertips and palms decreases with the wrist twisted.

2. Strength

The risk associated with applying power depends on the type of movement, the body part applying the force and other factors involved in the movement.

High levels of force can be considered as causal factors in the development of disorders due to long-term excessive unilateral exposure (LEXUE). Gripping or holding small objects with fingers and fingertips (so called "pinching") requires 4-times more effort than the power grip (with the thumb juxtaposed to other fingers).

3. Frequency or repetitiveness (monotonous work)

This refers to the duration of work cycles. The work is considered to be monotonous if the work cycle lasts less than 30 seconds, or if more than 50% of the work cycle is devoted to the performance of identical basic movements. If the work cycle exceeds 30 seconds or if less than 50% of the work cycle requires performance of identical basic labour movements, risk of monotony is low.

The risk arising from monotonous work also depends on the occurrence of other risk factors, related to the continuous loading of the same muscle.

4. Recovery time

In order to avoid damage due to long-term excessive unilateral exposure (LEXUE), each loading should be followed by adequate rest. The regime of work and rest can be determined in detail on the basis of energy expenditure (22, 23, 24). The time for recovery also depends on the number of cycles per day and per week.

It is considered beneficial for operators working in sitting positions to have a short break after each hour of working. When working in a standing position, it is advised to have short breaks (up to 10 minutes) after every half an hour of work. Damage due to long-term excessive unilateral exposure is reported to occur more frequently in the jobs with work cycles lasting 30 seconds, and if more than 50% of the work cycle is performed by the identical basic labour movements.

5. Individual factors

Intra-individual variability of an employee may, along with the workplace factors, increase the level of risk in terms of ergonomics. Arthritis, endocrine disorders, vitamin B6 deficiency, diabetes, pregnancy etc. may

signal a predisposition of some employees to the damage associated with the long-term excessive unilateral exposure.

6. Static load

During the process of dynamic loading, the contraction and relaxation of muscles pump fresh blood, thus providing a continuous supply of oxygen and nutrients and simultaneously removing waste products. Heavy static work requires the muscle to use its own oxygen and nutrients supply, and the metabolites resulting from the muscle activity are not discharged. Local hypoxia and accumulation of lactic acid thus cause pain and fatigue in the loaded muscles.

Examples of static load at work are as follows: keeping arms raised for a long time, holding objects in raised arms, pushing and pulling heavy loads and objects, standing in one place, tilting the head etc.

It is believed that static work can be performed several hours a day without the symptoms of fatigue if the force exerted does not exceed 8% of the maximum load force of muscle.

7. Local mechanical load

This risk factor is associated with contact of the body with sharp edges in the workplace and also unsuitably shaped tool handles. Pressure on soft tissues through the handles of tools causes an increased vibration effect. Pressure on forearms e.g. on the edge of a table causes a painful local deformation of the periosteum. The suffering person then reflexively raises his/her arms at work, so that the sore part of the forearm does not rest on the edge of the table. This results in an increased unilateral loading on the shoulder girdle and associated structures.

8. *Temperature*

Using tools in a cold environment can result in the deterioration of handling ability due to a decrease in tactile sensitivity. Overloading the muscles in order to firmly grasp the tool may increase ergonomic risk. The heat load in hot and humid working environments increases the effort of the whole organism, leading to its overheating (22, 23). In addition, if the tabletop of a device has too high or too low a tactile temperature this can lead to a forced labour position, similarly to the mechanical local effect of edges on lifting the forearm at work.

Individual values, i. e. the range of optimum and acceptable values of microclimatic conditions for warm periods of the year and different work classes as specified by the Government Regulation No. 247/2006 are shown in the Table below (25):

RANGE OF THE OPTIMUM AND ACCEPTABLE VALUES OF MICROCLIMATIC CONDITIONS FOR THE WARM PERIODS OF THE YEAR (49) Table 1

Work class	**Operative temperature t_o [°C]**		**Acceptable speed of air convection v_a [m.s^{-1}]**	**Acceptable specific humidity rh [%]**
	optimum	**tolerable**		
1a (sitting work with minimum movement)	21-25	20-28	≤ 0.2	30-70
1b (sitting work with random walking and handling light objects)	20-24	18-26	≤ 0.3	
1c (sitting work with constant involvement of both hands and arms connected with handling objects up to 10 kg)	18-22	16-25	≤ 0.3	
2 (work involving arms and trunk, handling heavier objects)	16-19	12-24	0.1-0.3	

9. Vibrations

Working with vibrating tools and equipment, especially with simultaneous exposure to cold, can cause diseases of the bones, joints, muscles, blood vessels and nerves of the extremities (22, 23).

The body of an employee can move and vibrate in one or more directions. Transfer plane is described by the orthogonal plane consisting of a set of X, Y and Z axes, where X-axis is of the back-front direction, Y-axis is of the right-left direction the Z-axis is of the feet-head direction. Figure 1 shows an example of a person standing or sitting on a plane vibrating along the Z-axis. If the observed person is lying, the vibration occurs along X-axis (2).

The negative effect of vibrations is mainly reflected in the resonance of the human body or its parts. The impact may induce changes of the functions of nerves, vascular system, musculoskeletal system, bones, joints, tendons and cartilage. The effect of vibrations may increase physical and mental fatigue of employees, leading e.g. to incidence of injuries.

10. Other risk factors

A lack of freedom in decision-making within working activities when the employee is being constantly controlled by someone else can be also considered a risk factor. Additional risk factors comprise the content and scope of the work when employee performs only one task without being allowed to develop new skills and solve new tasks. Other factors include social aspects of the work organisation, uncontrollable disorders, task-work, severity of the work unit as well as shift work.

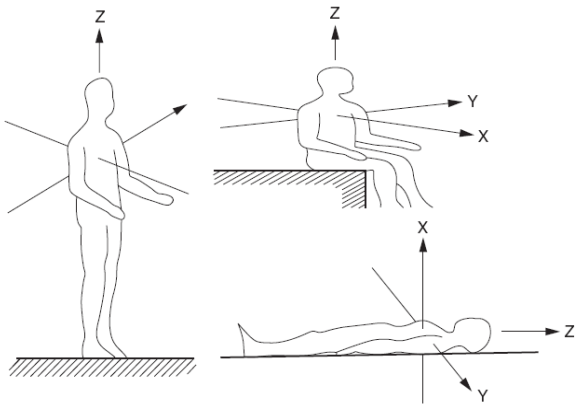


Fig. 1 *Direction of vibrations in relation to the torso (2)*

In terms of ergonomics, the pathogenic effect of cumulative risk factors are placed in the fact that the negative effect on workers' health does not become evident immediately, but after a longer period. It is first manifested in the form of disorders localised in the loaded parts of the musculoskeletal system. Unfavourable ergonomic working conditions even after a short occupational exposure can escalate these disorders into the pain syndromes requiring adequate urgent treatment as a measure of secondary prevention; otherwise they might result in permanent disability. In particularly adverse conditions in terms of ergonomics, incidence of such symptoms was recorded after only 4-month work exposure (26).

1.4 Trends influencing ergonomics implementation in business logistics

The current market globalisation and the fading global economic crisis affect all areas of the public, professional and personal life of each person.

Exposure to the changes in society, technological progress and the status of the workforce influence trends in the areas of ergonomics and business logistics.

The modern concept of ergonomics involves its division into microergonomics and macroergonomics, as can be seen in Figure 2. Advantage of such an approach to ergonomics lie in the pragmatic way of minimising the adverse effects of human diseases, mainly those profession-related. It closely observes the links between the causes and effects, while focusing on the elimination of the causes leading to health hazards, injuries of employees and, ultimately, to the reduced economic power of the enterprise.

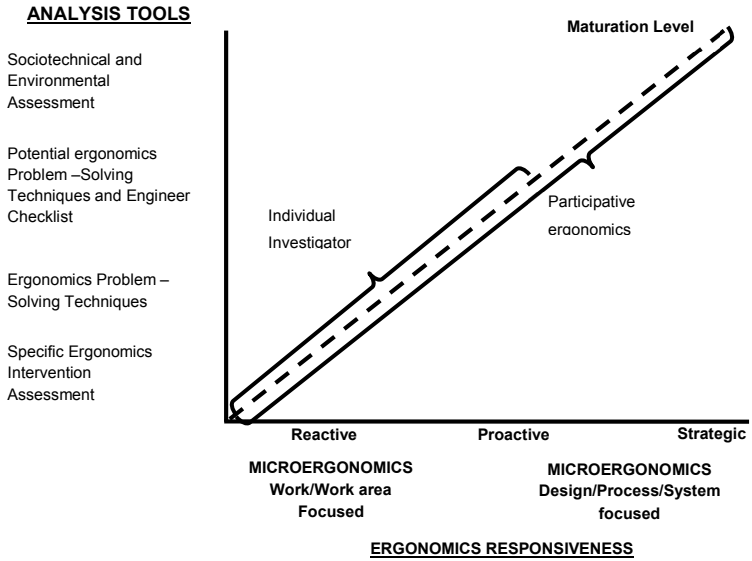


Fig. 2 *The continuous evolution and maturation of the ergonomics process (23)*

Microergonomics is seen as an approach to ergonomics that emphasises the exploration of the man-machine relations at a detailed level, as opposed to external factors (27). Microergonomics is defined as the sum of activities focused on solving everyday business problems and increasing the human labour efficiency (28). It typically applies operational approaches, while employing the principles of participatory ergonomics. Human work is considered effective if employees can perform work tasks so as to meet qualitative and quantitative production requirements without deteriorating their own health. In order to increase competitiveness in the market, there is an effort to train or hire the most versatile staff and to equip the operation sites with the flexible multi-purpose devices so that the enterprise can use the widest range of business opportunities for responding to the state of supply and demand in the market. Under these conditions, ergonomics is not only a question of humanity and ethics, but it becomes also an object of economic activities (28).

Microergonomics systematically deals with personnel issues related to the impact of work and working environment within the ergonomic programmes through ergonomic analyses. The aim is to detect the negative impact of modifiable and unmodifiable factors on the exposed employees in the form of complaints indicating shortcomings in terms of the workplace ergonomics, and following ergonomic rationalisation. Unlike in the macroergonomic approximate approach, problem-solving here continues until the complete elimination of the encountered disorders, the achievement of a positive impact on health of the exposed workers, and cost benefits (29).

Practically verified microergonomic knowledge is generalised within macroergonomics where it is scientifically reviewed and summarised in the

databases and programmes that then serve as the basis for enterprises. It also provides the data for developing the strategies for sustainable development on a global scale (i.e. microsolutions to macro problems).

Macroergonomics can be understood as an approach that examines the business environment, corporate culture, history and objectives that are all defined very broadly (30).

Macroergonomics applies mainly proactive approaches, collects and integrates the knowledge of all disciplines and applied research into the databases, the utilisation of which will facilitate and streamline labour while achieving economic benefits (42). It creates databases and models for global use. These databases are applied in the development of national legislation and the development of strategies for designing new work and organisational systems as well as their rationalisation within microergonomics. It is implemented either in the scientific institutions or large developed companies generating enough knowledge of microergonomics within the implementation of the ergonomics programs in plants (29).

Macroergonomics actually includes the original understanding of ergonomics as a whole, and focuses mainly on the activities related to the development of new devices and systems along with the development of ergonomics databases. Within the solution, there is an effort to develop a proactive approach; i.e. the solution should be based on the applicable law and it should use high quality data that accurately characterises the population for which the solution is intended. It is worth to note, however, that the high quality data and methods reflect the true reality only with a certain probability, and may be therefore considered approximate. This category includes for example, the direct use of anthropometric dimensions in

arranging a workplace, application of the methods such as RULA and REBA, various calculations, check forms, or even calculations and the graphic software methods. Such a solution, while respecting the requirements of laws, does not however necessarily guarantee the elimination of health damage.

In terms of improvement of business logistics activities, purchase processes, storage, production and sales in business logistics, enterprises are trying to lean the above-mentioned processes by applying principles of the Kaizen philosophy in the form of continuous and sustainable improvement.

The Kaizen approach was popularised by Masaaki Imai as an expression consisting of two words “Kai” = change or action to remedy and “Zen” = good, better. Kaizen in Japanese means improvement (31) of one’s personal life, home life, social life and working life. In a workplace application, Kaizen means continuous improvement, covering both managers and ordinary employees. The Kaizen philosophy assumes that our way of life - whether professional, social or family life - should strive for continuous improvement (22). The concept of Kaizen frequently appears as Gemba Kaizen. Gemba is the actual place where the activity is carried out, which is the subject of improvement and where value is added. In most businesses, such place is a workshop, production site, warehouse, process and material handling etc.

Kaizen also means continuous improvement involving generating ideas, running projects, innovating procedures and creating values. In the Kaizen philosophy, improvement is a slow, gradual process, the results of which become visible after a longer time. Business activities in terms of the Kaizen concept can be divided into two types: maintenance and improvement (31, 32, 33). Maintenance activities are related to the activities aimed at

maintaining the current technological, managerial and operational standards. The improvement relates to the activities aimed at improving the current standards in order to increase the actual performance (31, 32, 33).

Both types of activities are mutually parallel. Besides maintaining the required level of performance, it is also necessary to seek new methods, new technologies, more efficient equipment etc. In well established companies, each employee should have both types of activities in his/her job description. The ratio of the two components should reflect the hierarchical position of an individual in the company. Top management should devote a greater part of their time to the improvement of actions in relation to the company strategic prospects, market demands and the strength of competition. On the other hand, production employees should spend most of their time by running maintenance activities (33).

The Kaizen approach is therefore based on two concepts: *continuity* - nothing in the world is still, everything keeps changing and evolving (markets, customers and their needs) and *improvement* - everything can be improved (quality, delivery performance, high costs, productivity, etc.).

Key Kaizen principles comprise (34):

- ***Any improvement, even seemingly less important, is worth attention***,
- ***Kaizen is open for everyone,*** anyone can participate in the process of improvement,
- ***Before introducing an improvement, it must be accurately analysed*** regarding its current state and possible positive effects and the risks that might arise in the process of implementation,
- ***Kaizen represents 50% of a good manager's work***,

- ***It highlights the role of a working team***, promoting participation and initiative of employees in problem-solving,
- ***It seeks solutions through meetings of working team***,
- ***It informs*** regarding the current state in the field, challenges and business objectives, pointing to the areas that make up logistics bottlenecks,
- ***It needs strong support from the company management*** (Kaizen is based on the activities from the bottom, but requires strong support from the top),
- ***It creates organisational prerequisites*** for improving the communication of staff (consulting rooms, visits of management to production site, communication during the execution of logistic activities, etc.),
- ***It motivates employees*** - participation in the success (material and financial rewards of good solutions).

Three key factors of Kaizen improvement as reported by (31, 32, 33) are:

- ***elimination of redundancy and ineffectiveness***,
- ***5S method – system of workplace design***,
- ***Standardisation***.

1.5 Possibilities of ergonomics implementation in business logistics

The importance of ergonomics implementation in business logistics is determined by the objective risk factors forming the system of man-machine-working environment.

The occurrence of critical values in the working process indicates some deficiencies in the system of work in terms of ergonomics, such as disorders of musculoskeletal system, sickness rate, accident rate, fluctuation, absence, cost of compensation associated with emerging diseases, reduction of work quality and defectiveness in production (16).

Business logistics should pay attention to the disorders of employees, which are due to the effects of work and the working environment. The disorders may indicate insufficient adaptation of work and working conditions to the capabilities of workers or a long-term, excessive and unilateral exposure of employees to cumulative pathogenic risk factors.

Both ergonomics representing a set of methods and tools for the prevention and rationalisation of labour and business logistics as a subsystem of enterprise management have certain aims.

The aim of logistics' is to: *"Ensuring that customer requirements for supplies and services* are *at the required level and at optimised total cost*."

The aim of ergonomics is the efficiency of human labour via "*Ensuring human health, i.e. physical, mental and social well-being along with economic benefits*."

The combination of these aims may result in overlapping of individual areas and possibilities of satisfying customer requirements for supplies and services at the required level, while assuring the protection of human health in all main and auxiliary processes needed to meet the customers' demands. This blending may contribute to the consistency of individual objectives, thereby achieving both customers and employees' satisfaction, and thus also satisfaction of the company.

When defining the possibilities of ergonomics application in business logistics, it is necessary to respect its classification regarding the scope, characteristics of work processes and type of the activities performed.

Business logistics of a manufacturing company follows all the tangible and intangible components of the logistics chain, starting from procurement of raw materials and parts, through manufacturing, assembly and storage, up to the final distribution to customers. Ceniga and Majerčák (7) indicate that logistics is a business function that passes through the whole enterprise while managing, integrating, regulating and controlling all flows of materials, products, information and finance and other related activities, such as inventory, transportation, warehousing, material handling and packaging. Business logistics as a subsystem of an enterprise (Fig. 3) can be divided into:

- ***supply logistics***,
- ***production logistics***,
- ***distribution logistics***.

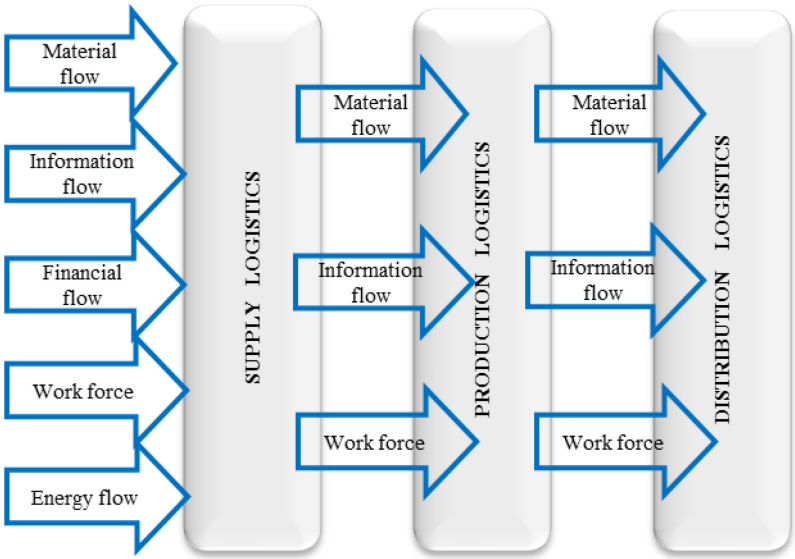


Fig. 3 *Structure of business logistics*

Supply logistics

Supply logistics (inbound logistics) is a link of the logistics chain, which carries out the tasks aimed at providing the necessary amount of production items, raw and auxiliary materials supplied to the warehouse or directly to the production, and possibly also other activities. Along with the procurement of the raw and auxiliary materials, supply logistics (including information flow) supplies the required amount of material to the right place, in the right quantity and required quality.

Figure 4 illustrates the area of logistics and its individual sectors as defined in the sources (7, 8, 12, 35, 36).

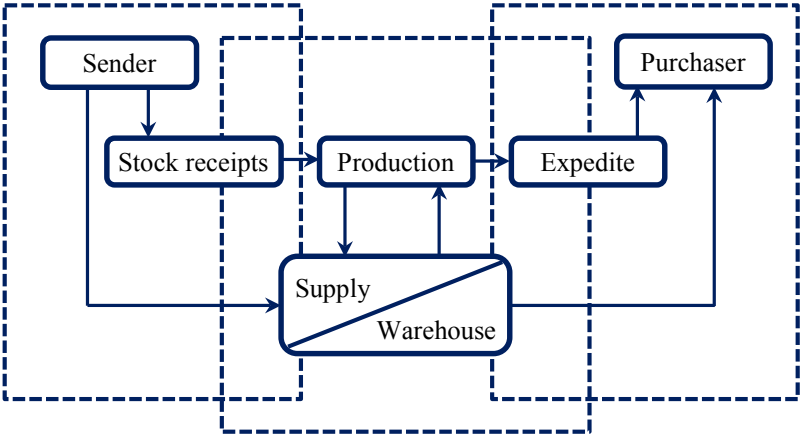


Fig. 4 *Scope of elementary areas of logistics (7, 8, 12, 35, 36)*

As mentioned above, supply logistics provides the necessary material, raw and auxiliary materials either directly to production or warehouse. It is not always possible to supply directly to the production site, e.g. via Just-In-Time; it is therefore essential to provide input warehouses for the inventory stocks.

Some references tend to define the role of supply logistics as consisting of (8, 12, 37):

- ***purchase roles***,
- ***supply and acquisition roles***.

The key purchase roles are primarily related to marketing activities (market research) as well as price and value analysis. Based on the surveys conducted, the following activities are carried out: selection of suppliers, negotiations with suppliers, preparation, provision and conclusion of supply contracts. According to (8, 38), the objective of purchase may be optimisation of the cost of buying individual items.

Supply and procurement roles then include the activities related to the administrative and physical material handling, i.e. the activities focused on planning, management and control of the material and information flows, intake and physical receipt of the material, its qualitative and quantitative check, handling and storing, and preparation for production.

The objective of supply and procurement can be a suitable way of supplying the enterprise with all inputs at the optimum costs of physical activities (8, 38).

According to the survey carried out in the European Union (except of France), 8.6% of employees suffered from the work-related health problems primarily in the areas of bones, joints, muscles, spine, neck, arms and hands (39).

As mentioned above, the supply logistics provides marketing activities as well as the activities related to the physical manipulation of materials. Materials handling, warehousing of goods and its preparation for production in particular represent one of the greatest risks in terms of ergonomics, leading to long-term excessive unilateral exposure of the organism.

The results of the Slovak Republic Health Statistical Yearbook 2011 of the *National Health Information Centre* indicate that mostly diseases of bones, joints and tendons of upper extremities due to long-term excessive unilateral exposure are the cause of occupational diseases, representing an increase of up to 115.7% since 1993 (40).

The results show the urgent objective necessity to deal with ergonomics as a support tool of ensuring the efficiency of human labour by creating the optimum working conditions and environment in order to reduce the given percentage in the field of inbound logistics. The following table shows the

basic tasks and the use of ergonomics in the field of inbound logistics processes.

Production logistics

Several authors (7, 12, 36, 41) cite the following description of production logistics: “The term production logistics means a set of the tasks and measures for the preparation and execution of the manufacturing process. It includes all activities related to the material and information flows of raw materials, auxiliary materials and production materials from the warehouse to the production and storage of semi-finished and purchased parts through various steps of the manufacturing process, including any buffer stores, through the installation up to the warehouse of finished goods”.

The main factors affecting the nature of production logistics may include the development of the optimum production structure of enterprise, planning and management of the production process, planning the material consumption, planning the maintenance and repair of machinery and equipment, development of favourable conditions for the workforce, efficient use of available space and premises, high flexibility in the utilisation of buildings, structures and equipment, and the control of the manufacturing process (35).

APPLICATION OF ERGONOMICS PRINCIPLES IN THE AREA OF SUPPLY LOGISTICS Table 2

Supply logistics	Space for the application of ergonomic principles
Roles and activities of purchase: ➢ market research, ➢ negotiations with suppliers, ➢ selection of suppliers, ➢ preparation and elaboration of contracts. **Roles and activities of acquisition and supply:** ➢ receipt of goods, ➢ physical receipt of material (unloading) ➢ verification of quantity and quality of material (weighing, measuring) ➢ factory/on-site transportation, ➢ material handling, ➢ material storage ➢ preparing material for production ➢ planning, management and control of the material and information flows	➢ adjusting dimensional parameters of the workplace, ➢ shortening reach distances, ➢ establishing a suitable regime of work and rest, ➢ providing appropriate microclimate conditions, ➢ adequate introductory instructions and training of employees, ➢ providing conditions for work with VDU, ➢ providing appropriate PPE, ➢ selecting suitable staff, ➢ choosing appropriate tools, ➢ choosing appropriate handling units and equipment, ➢ minimising prolonged, excessive unilateral load, ➢ creating conditions for work in suitable working positions, ➢ choosing the right job positions while minimising static position and high frequency motions, ➢ adaptation scoping reach distances in material handling, ➢ minimising handling above shoulder height, ➢ avoiding material handling with arms outstretched in front of the torso, raising the forearm while lowering elbows ➢ maintaining a neutral wrist position, ➢ preventing deep flexion forward connected with the rotation of the torso, ➢ involving mainly large muscle groups when handling objects manually

Under the current turbulent changes taking place in the markets, it is vital for enterprises to meet the requirement for the high availability and reliability of supplies, meet the changing customer demands, reduce production times and meet delivery times. This can be done through

interventions into storage, interoperational transportation and handling of materials.

Shortening of the production time can be achieved through the application of new production systems, structuring production and destocking. However, integration of operations in complex units, i.e. reduction of the number of contact points seems to be a significantly more efficient procedure. Integrating and streamlining material flow in production, minimising inventory and maximising flexibility in meeting customer requirements imply the application of effective fundamental logistics approaches (8, 12).

Logistics approaches in production can be based on the centralisation or decentralisation of the management activities that directly affect the course of production (42).

Basic classification of the production management systems influencing the effectiveness of employees' performance and their physical and psychological stress can be done on the path of product through production. Many authors divide the systems into two categories: "Push" and "Pull" production management. The "Push" type production systems are those in which the production of goods is governed by a solid plan with the key role of corporate objectives (e.g. maximum utilisation of corporate resources). "Pull" type systems, on the contrary, are those in which the start of processing a new product is conditioned by the completion of the previous product. In such case, market goals (e.g. flexible delivery of products to the market) become significant (42). Characteristics of the management system for different types of production are given in Table 3.

In both cases, there is the pressure to quickly implement high quality business operations, particularly those carried out by the employees working in manufacturing.

It is a company interest to provide the working conditions with a minimised impact of stress, while focusing on the:

- ***elimination of redundant handling operations***,
- ***reduction of power consumption of handling operations***,
- ***mechanisation and automation of handling operations***,
- ***optimisation of workplace layout and workplace arrangement***,
- ***work and workplaces organisation, working environment***,
- ***selection of employees for handling processes***.

One of the main problems of production logistics is the development of favourable conditions for the workforce (35).

In the field of production logistics, employees are involved in the production process, particularly through the activities in areas such as: transportation, storage and handling in production, pre-production storage of materials and semi-finished goods, material handling and picking parts for different levels of the production phase, inter-operational and operational transportation, interoperable storage, handling during assembly of sub-groups and finished products, handling finished products, packaging and distribution.

CHARACTERISTICS OF MANAGEMENT FOR VARIOUS PRODUCTION TYPES (24) Table 3

Disposition layout of production	**Type of production**			
	Job shop	**Small batch production**	**Large-batch production**	**Mass production**
Production in one place or machine	MRP, MRP II	MRP, MRP II		
Workshop principle - individual machines	MRP, MRP II	MRP, MRP II		
Workshop principle – function groups, nests		OPT, BOA	OPT, BOA	
Assembly lines		OPT, BOA	OPT, BOA, KANBAN, MRP II, JIT	KANBAN, MRP II, JIT
Assembly lines of mass production			MRP II, JIT	MRP II, JIT

In the area of production, about 54% of men and 38% of women are exposed to one or more factors which may, in terms of ergonomics, affect their physical health; 25% of men and 23% of women are exposed to the factors adversely affecting also their psychological well-being (39).

Based on the results mentioned above, it is necessary to apply ergonomics in the field of business logistics, e.g. by introducing the measures listed in Table 4.

APPLICATION OF THE ERGONOMIC PRINCIPLES
IN THE FIELD OF PRODUCTION LOGISTICS Table 4

Production logistics	Space for the application of ergonomic principles
Roles and activities of production logistics: ➢ applying decision-making procedures in production, ➢ designing and optimizing material flows in production, design production disposition, ➢ managing production, ➢ operational production planning, ➢ production management, ➢ managing production inventory, ➢ optimizing batches size, ➢ manufacturing lead time reduction, ➢ transporting, storing and handling in production, ➢ pre-production storage of materials and intermediate goods, which is closely linked to the supply, ➢ handling and preparation of material for different levels of production phases of parts, ➢ inter-operational and operational (technology) transport,	➢ minimising static load of muscles and MSS, ➢ reducing the force required to operate the machinery and tools, ➢ selecting the appropriate type and location of tell tales and controls, ➢ minimising the noise and vibration affecting an employee in the manufacturing process, ➢ preferred choice of instruments and tools, the use of which requires the involvement of the arm, not just finger and pinching, ➢ eliminate sharp edges, ➢ shortening reach distances in material handling, ➢ minimising handling above shoulder height, ➢ avoiding manipulation with arms outstretched in front of the torso (raising forearm while lowering elbows when handling material) ➢ choosing an appropriate level of mechanisation and automation in handling loads, ➢ reducing manual handling to a minimum, ➢ reducing the weight of the load handled manually, ➢ possibility of grasping the material handled with both hands, ➢ reducing the distance necessary to transport the loads handles manually, ➢ choosing appropriate handling units (containers, pallets), ➢ reducing rapid and repetitive movements during the production process, ➢ choosing appropriate staff rotation, ➢ minimising monotonous work.

Distribution logistics

Distribution logistics (outbound logistics) can be described as the area dealing with the problems of spanning the spatial and temporal differences between the production and consumption of products (8, 12, 35). It includes all activities (i.e. all transport and storage movements of goods) necessary to ensure that the product passes continuously from the production site to the final point in the distribution channel (the products pass from the manufacturer to customers through a network of sales stores, in special cases a direct flow of goods based on the principle of production - customer, or sender - customer), including the required information, management and checking activities.

The above-mentioned activities comprise (7, 8, 12):

- ***storage***,
- ***transportation***,
- ***packaging, sorting, weighing and measuring***,
- ***warehousing***,
- ***handling orders***.

The aim of distribution logistics is to place the right product to the right place at the right time in the right quantity and quality. Customers put emphasis on reducing their own inventories, and they therefore prefer to order smaller quantities at shorter intervals and at the maximum synchronisation with their own needs (procurement logistics of customer) (35).

The main role of distribution logistics is as follows: building a distribution network and management of distribution activities, planning and designing the layout of distribution warehouses, implementation of storage,

order processing and packaging of goods, storage of goods at all interstages of distribution up to the end consumer, transportation of products to the end consumer, concentration of certain assortment of goods at the point of sale, determination of the necessary number of storage stages, determination of the number of stores at each interstage, their locations, unloading goods and providing the loading operations, quality inspection of goods supplied (e.g. its refinement by storage), decision-making regarding the size and location of production, launching the products on the market and minimising the transportation and total distribution costs (35).

In distribution logistics, employees enter the working process by performing the activities associated with loading operations, internal transport, packaging and shipment. During these activities, workers are exposed to risk factors in terms of ergonomics, such as static load, abnormal joint positions, vibrations, local mechanical stress, temperature etc.

In 2011, long-term illnesses due to unilateral and excessive exposure of limbs represented 43.43% of the total number of occupational diseases and health damage; hearing loss represented 12.06% and diseases of vibration 10.72% (40). The above-mentioned diseases are caused mainly by the activities carried out by the people in the field of production and distribution; the role of ergonomics in the field of distribution logistics is therefore vital.

From 1997 to 2011, the compensation paid for occupational accidents and occupational diseases rose from € 5.245.781 to € 41.280.386, representing an increase of 786.93% (43, 44). It confirms the importance of ergonomics as an effective preventive tool of the health damage and occupational diseases in all areas of working life, such as logistics support management in the field of transport, storage, manufacturing, handling and

distribution. Table 5 lists the opportunities and scope for the application of ergonomics in the distribution logistics.

UTILISING ERGONOMIC PRINCIPLES IN THE FIELD OF DISTRIBUTION LOGISTICS Table 5

Distribution logistics	Areas for utilising ergonomic principles
Roles and activities of distribution logistics: ➢ processing orders, ➢ storage, ➢ picking process, ➢ packing, sorting, weighing, measuring, ➢ checking and handing orders, ➢ transportation, ➢ transport between production and trade company, as a part of the sales logistics	➢ adapting the dimension parameters of a workplace, ➢ shortening reaching distances, ➢ selection of suitable work/rest regime, ➢ providing suitable microclimatic conditions, ➢ providing suitable lighting, ➢ elimination of noise and vibrations, ➢ providing conditions for working with VDU, ➢ designing the criteria for selection of employees regarding their age and health capacity, ➢ elimination of extreme positions of the upper extremities joints, ➢ providing sufficient space for employee movements, ➢ eliminate low flexion forward and flexion combined with rotation of the trunk, ➢ minimise unnatural working positions (kneeling, lying, work above the arms level) ➢ minimise the work requiring lifting and carrying heavy objects, frequent finger movements frequent repetitions, high psychical and physical stress, ➢ work with altering hands.

Ergonomic solutions for the field of business logistics

The role of ergonomics in the field of business logistics is to carry out the tasks associated with monitoring the impact of work, work means and the

working environment on the health of employees, and subsequently execute the activities aimed at eliminating the negative impacts of work performance via introducing appropriately defined measures. There are generally two approaches to implementing an ergonomic solution.

Approach 1 is mainly applied in the development of new products, machinery and equipment. Proactive implementation of preventive measures helps eliminate the risk factors which are due to long-term excessive unilateral exposure. The ergonomic design requires the application of ergonomics at all stages of technological solutions (16).

Approach 2 is a model of participatory ergonomics (16) which is used in companies mainly within their ergonomics programmes, such as the process of improving working conditions by using group problem solving. The group usually consists of representatives of company management, workers, and, if necessary, technicians. The ergonomic programmes apply the above-mentioned model of participatory ergonomics as a process of improving the working conditions by using the methods of group problem solving in groups of employees.

The process is generally accomplished within a 5-stage cycle (16, 45, 46):

- ***stage I*** – identification of a problem in the system,
- ***stage II*** – analysis of the problem causes and development of the solution,
- ***stage III*** – solution itself,
- ***stage IV*** – implementation of the solution into practice,
- ***stage V*** – evaluation of the solution benefits.

Fig. 5 *Ergonomics process*

The proposed 5-stage cycle for the process of ergonomic solution development, is generally recommended as a procedure for solving problems in terms of ergonomics. The stated problems can be broadly defined and characterised by poor specification and insufficient determination of what exactly needs to be done, how to achieve it, what procedures and tools can be used in order to improve the working conditions and working environment settings, how to set goals and identify the indicators to monitor the goals and how to proceed in case of the ergonomic solution failure.

Non-application of ergonomics in enterprises may result in a decrease of the employees performance and the quality of their work, and thereby a decrease of the enterprise competitiveness. This may consequently increase the cost of hiring and training new employees as well as the cost of the treatment reimbursement and the retirement pay to the affected workers.

In business logistics, ergonomics can be primarily implemented on the level of physical flows of materials (operations), where employees are exposed to risk factors in terms of ergonomics. The application of ergonomics requires support on an active management level (making strategies) and logistics management (in planning, managing and checking the operations performed).

Ergonomics can be primarily applied in the following activities:

- ***supply logistics*** – receiving, unloading, shipment, storage and handling goods,
- ***production logistics*** – manufacturing, assembly, inter-operational handling, operating machines and equipment, storage, check, commissioning,
- ***distribution logistics*** – sorting, classifying, storing, commissioning, packaging, palletising, loading, recycling.

Our aim is to define the status of ergonomics in business logistics as an important tool for sustainable competitiveness of the company. The following specification was therefore developed:

Ergonomics in the field of business logistics can be seen as a comprehensive approach contributing to the optimisation of the organisational, working and technical systems while respecting the relevant personnel, technological and environmental changes as well as their interactions. It includes activities aimed at developing and maintaining a flexible and ergonomically acceptable environment, supporting a healthy, comfortable and productive workplace, providing sustainable competitiveness of the company through human work efficiency while

meeting the customer requirements for supplies and services at the required level and optimised total costs.

The following chapter describes the general process of ergonomic solutions and specifies the stages, steps and tools needed to implement ergonomics in various areas of business logistics.

At the same time, the author will try to enhance the process of ergonomic solutions by employing the Kaizen philosophy, i.e. continuous improvement through small incremental steps, with simultaneous elimination of waste, implementation of the measures of economy and standardisation, and designing and innovating projects and creating values.

A limited focus on human health seems to be a disadvantage of Kaizen; the present monograph therefore focuses on the pragmatic, i.e. a factual and unbiased approach to human work efficiency and the usefulness of problem-solving in terms of the work of employees and their working environment.

2. CURRENT STATE OF THE ERGONOMICS IMPLEMENTATION IN BUSINESS LOGISTICS IN SELECTED COMPANIES IN THE SLOVAK REPUBLIC

This chapter focuses on the analysis and evaluation of the current state of the ergonomics implementation in the fundamental areas of business logistics in selected industrial enterprises in the Slovak Republic. It primarily discusses the impact of labour impact, arrangements of working conditions as well as the impact of modifiable and unmodifiable risk factors on the formation of disorders and damage of the musculoskeletal system (MSS) of employees.

2.1 Research procedure

To investigate the application of ergonomics in business logistics, three medium and large industrial manufacturing companies were selected (the size is defined by the number of employees from 50 to 250 and more than 250). We established cooperation with the companies operating in the engineering and electro-technical industries. Cooperation of the companies was on the condition of ensuring their anonymity, and they are therefore denoted in this monograph by the first letters of the alphabet, i.e. A, B and C. Data collection in the survey conducted was carried out using an extrapolation method of asking questions through a questionnaire distributed to employees and workers actively engaged in all logistics processes, based on their informed consent.

Data collection through the questionnaire using direct observations served as the initial approximation to determine the state of ergonomics implementation and the impact of work, industrial machines and tools, the

environment and work organisation on the formation of disorders and work-related illnesses in various areas of business logistics. Based on the initial analysis, we obtained data which was discussed with representatives of the company's management. The analysis also allowed us to select statistically significant factors (evaluated characteristics) from statistically insignificant ones, thus achieving the results that helped identify the problem areas for employees. The data obtained was used to administer the secondary analysis focused on monitoring the effects of the selected factors.

Distribution of the questionnaire was provided in person at the premises of the individual enterprises based on a sample of 430 employees. The total return rate represented 418 filled-in questionnaires, representing **97.21%.** A modified Nordic Questionnaire (50) was chosen based on the following facts:

- ***simplicity*** – simply, clearly, transparently and objectively defined questions, user-friendly filling-in,
- ***unambiguity*** – clearly asked questions,
- ***consistency*** – logical structure aligned with the nature of data, database structure and data processing requirements,
- ***analysability*** – characteristics of the reference file (age, gender, physical characteristics) along with verification of homogeneity of the studied groups in terms of profession and workload, incidence, intensity and localisation of problems and MSS disorders, factors and work and working conditions as subjectively evaluated by employees, as well as the symptoms and factors which may affect the incidence and degree of MSS disorders of staff,
- ***respecting respondents*** – formulation of questions framed according to the target group of respondents,

- ***respecting anonymity of respondents*** in accordance with the protection of personal data with the consent of the Ethics Committee of the Institute of Preventive and Clinical Medicine in Bratislava.

The following hypotheses were statistically tested within the survey:

- ***Hypothesis H1*** – We assumed that 2/3 of employees experienced MSS disorders,
- ***Hypothesis H2*** - 1/4 of employees were forced to seek professional medical help due to the emergence of MSS disorders,
- ***Hypothesis H3*** - Selected factors of work and working environment were involved in causing MSS disorders.

Evaluation of the data obtained by the questionnaire survey was supported by calculating the statistical characteristics of the parametric and non-parametric features such as:

- arithmetic mean $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$
- minimum value
- median Q_{50} ,
- maximum value

standard deviation

$$s = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n-1}}$$

25. percentile = $\frac{Q_{25}}{100}$

75. percentile = $\frac{Q_{75}}{100}$

Distribution or frequencies of alternatives of individual parameters are compared and expressed in a percentage with a 95% confidential limit.

The General Nordic Questionnaire was used to evaluate the effects of selected basic factors on the rise of disorders and damage to the health of employees.

The results of the questionnaire and direct observation confirmed or disproved the hypotheses tested. If the effect of one of the monitored factors proves to be statistically significant ($p < 0.05$), the hypothesis is correct, and, vice versa, if any of the monitored factors proves to be statistically insignificant, there is not sufficient evidence to reject the hypothesis; i.e. the identified difference may be random. This step will provide a basis for the secondary analysis phase, which is monitoring statistically significant factors.

Significance of differences in the case of comparison is characterised by probability "p" of refusal of the original hypothesis and acceptance of the alternative one. The latter discusses the significance of the difference of observed characters at the following levels:

- ***significant difference***,
  significance level of **5%** ($p \leq 0.05$ a > 0.01) marked *,
- ***highly significant difference*,**
  significance level of **1%** ($p \leq 0.01$ a > 0.001) marked **,
- ***extraordinary high significant difference***,
  significance level of **0.1%** ($p \leq 0.001$) marked ***.

2.2 "A" Company

"A" Company is a production and technology enterprise with more than 100 years of history. The team of 129,000 employees offers customers a wide

range of products and services in various technology areas in more than 250 production sites worldwide. The Swedish stock-holding company currently covering seven divisions has operated in Slovakia since 1994. Its division that provides complete power solutions and services for the global IT and telecommunications market came to Slovakia in 2003. The division disposes technology expertise, global reach and a range of products and services to build and maintain the infrastructure of power and telecommunications networks. Products and solutions of the division range from the standard converters up to the complete energy partnership in the telecommunications industry.

2.2.1 Characteristics of the examined set of employees in "A" Company

Using a modified Nordic Questionnaire, 151 employees (56 women and 95 men) were examined out of the total of 155 addressed employees, which represents a return rate of 97.41%. Given the wide range of occupations with relatively low representation, it was necessary to classify the employees for the purposes of ergonomic analysis according to observed workload into working groups A, B, C, D, E, F and G.

A statistically highly significant difference is evident in the representation of men and women working in the observed B group (81.3% of men), C group (73.3% of men) and F group (96.4% of men). In terms of unmodifiable factors, men and women statistically significantly differ only in physical features such as body height, weight and BMI indicating the weight-height ratios, as it is common in the Central-European population.

2.2.2 Incidence, localisation and intensity of disorders and damages to the musculoskeletal system of employees in "A" Company

In terms of ergonomics, incidence of musculoskeletal disorders is an important indicator of deficiencies in a given work system. The incidence of disorders and their evaluation is discussed in the following pages.

As seen in Figure 6, the incidence of disorders in selected operations was claimed by 90.10% of all examined workers regardless of gender.

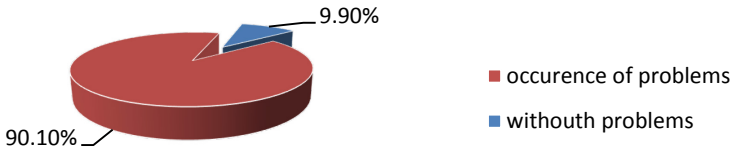


Fig. 6 *Incidence of MSS disorders of all examined employees in selected operations in "A" Company*

Results of the questionnaire suggest that 28.9% of respondents had to visit a doctor due to the incidence of musculoskeletal system disorders, as shown in Figure 7.

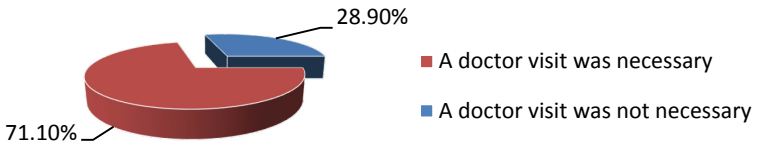


Fig. 7 *Doctor visit by examined employes in selected operations of "A" Company for the past year owing to the intensity of MSS disorders based on subjective data*

Figure 8 documents the incidence of fatigue of all examined employees; 29.6% of them felt tired even after a day of rest.

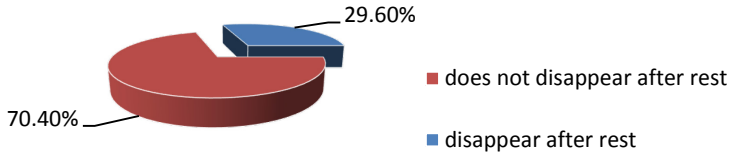


Fig. 8 *Incidence of symptoms and intensity of fatigue of the employees examined in the operations of "A" Company*

As evident in Table 6, the examined employees in all working groups and regardless of sex suffered from disorders in thoracic (chest) and lumbosacral (waist) parts of the spine in the past year. Generally, all groups reported disorders of the musculoskeletal system located in the neck, shoulders, hands and feet.

Similar intensity of MSS disorders localised in the neck, thoracic spine, lumbar spine and hands was reported in the working groups A, D, E and G.

The highest intensity of MSS disorders requiring a doctor visit in the past year was localised in the area of the lumbar spine. The working group D claimed similar intensity of such problems occurring also in the neck and thoracic spine.

INCIDENCE AND LOCALISATION OF MSS DISORDERS
OF THE EXAMINED EMPLOYEES IN WORKING GROUPS Table 6

LOCALISATION OF MSS DISORDERS	Incidence and localisation of MSS disorders in working groups for the past year							TOTAL n = 151
	B (n=16)	A (n=25)	**C** (n=15)	**E** (n=42)	**D** (n=10)	**F** (n=28)	**G** (n=15)	
Neck	**50.0**[2)]	**68.0**[1)]	**66.7**[2)]	**57.1**[3)]	**60.0**[2)]	39.3	**60.0**[2)]	56.3%
Shoulders	37.5	**48.0**[3)]	26.7	33.3	**70.0**[1)]	28.6	**40.0**[4)]	37.7%
Back (*thoracic region*)	**50.0**[2)]	**68.0**[1)]	**60.0**[3)]	**52.4**[4)]	**50.0**[3)]	**42.9**[2)]	**53.3**[3)]	53.6%
Elbows	6.3	8.0	20.0	16.7	20.0	14.3	6.7	13.2%
Croup (lumbosacral region)	**68.8**[1)]	**56.0**[2)]	**73.3**[1)]	**64.3**[1)]	**60.0**[2)]	**46.4**[1)]	**73.3**[1)]	61.6%
Hands/wrists	18.8	36.0	26.7	**59.5**[1)]	**60.0**[2)]	17.9	**40.0**[4)]	38.4%
Hips/thighs	6.3	12.0	6.7	14.3	10.0	10.7	13.3	11.3%
Knees	**50.0**[2)]	16.0	6.7	33.3	30.0	28.6	20.0	27.2%
Ankles/Feet	**43.8**[3)]	28.0	6.7	33.3	30.0	28.6	**40.0**[4)]	30.5%

2.2.3 Selected symptoms and factors influencing the incidence and intensity of disorders and damage to the musculoskeletal system of employees in "A" Company

Table 7 documents the total score of modifiable factors of work and working conditions in the monitored working groups as a percentage. The evaluation comprises only the percentage of the assessment expressed by marks 9 and 10 on the scale 1-10. A maximum of 5 factors with the highest rating are highlighted in the columns showing the assessment of work and working conditions. The Table shows that the most negative factors with the highest rating were identified by the staff in the working group G; the least factors were indicated in the working group A.

The incidence of musculoskeletal system disorders of the lowest intensity is an indicator of the work or working system deficiencies in terms of ergonomics. In assessing workplaces, it is necessary to consider both directly acting agents of work and the work environment along with the

factors indirectly related to professional activities, but possibly affecting the incidence and degree of MSS disorders.

PERCENTAGE OF RESPONSES INDICATING THE GIVEN FACTOR AS THE KEY PROBLEM (9 AND 10) ON A SCALE OF 1 TO 10 OF THE QUESTIONNAIRE IN THE WORKING GROUPS OF "A" COMPANY

Table 7

FACTORS of WORKING CONDITIONS	WORKING GROUPS							TOTAL n = 151
	A n = 25	B n = 16	C n = 15	E n = 42	D n = 10	F n = 28	G n = 15	
Microclimate	8.0%	**50.0%[1)]**	**20.0%[2)]**	**42.9%[1)]**	**60.0%[1)]**	**28.6%[1)]**	**66.7%[2)]**	36.4%
Long persistence in working position	**16.0%[1)]**	**18.8%[3)]**	6.7%	**33.3%[2)]**	**50.0%[2)]**	14.3%	**40.0%[5)]**	24.5%
Handling heavy material (weight of load)	8.0%	**18.8%[3)]**	0.0%	**28.6%[3)]**	20.0%	**21.4%[2)]**	**80.0%[1)]**	24.5%
Work at the limiting physical and mental possibilities	4.0%	**18.8%[3)]**	**13.3%[3)]**	21.4%	20.0%	**21.4%[2)]**	**46.7%[4)]**	19.9%
High pace of work	8.0%	**18.8%[3)]**	0.0%	21.4%	**30.0%[4)]**	10.7%	**60.0%[3)]**	19.2%
Quality of tools	4.0%	**18.8%[3)]**	**13.3%[3)]**	**33.3%[2)]**	**50.0%[2)]**	7.1%	13.3%	19.2%
Excessive bending forward and rotating trunk	8.0%	**25.0%[2)]**	0.0%	26.2%	**40.0%[3)]**	14.3%	20.0%	18.5%
Work after injury and illness	4.0%	12.5%	**13.3%[3)]**	26.2%	20.0%	10.7%	**46.7%[4)]**	18.5%
Forced labour position	**12.0%[2)]**	6.3%	**13.3%[3)]**	23.8%	30.0%	**17.9%[3)]**	20.0%	17.9%
Quality of introductory instructions and training	8.0%	12.5%	**13.3%[3)]**	23.8%	30.0%	7.1%	13.3%	15.2%
Quality of work organisation	**12.0%[2)]**	12.5%	**33.3%[1)]**	16.7%	10.0%	7.1%	6.7%	13.9%
Working overhead	4.0%	6.3%	6.7%	21.4%	20.0%	10.7%	20.0%	13.2%
Insufficient breaks (time to relax)	4.0%	6.3%	0.0%	14.3%	10.0%	10.7%	26.7%	10.6%
Repetitive and monotoneous work	4.0%	6.3%	0.0%	4.8%	**30.0%[4)]**	0.0%	20.0%	6.6%
Handling small objects	8.0%	6.3%	6.7%	2.4%	0.0%	7.1%	6.7%	5.3%

Generally, the most significant modifiable factor influencing the incidence of MSS disorders is **"Repetitive work"**. Factors such as **"Long persistence in a working position"**, **"Insufficient breaks"** and **"Work after injury and illness"** may signal a tendency (Table 8).

EVALUATION OF THE TOTAL NEGATIVE INFLUENCE OF MODIFIABLE FACTORS OF WORK AND WORKING ENVIRONMENT BY THE EMPLOYEES OF "A" COMPANY AND OF THE INCIDENCE OF MSS DISORDERS Table 8

MODIFIABLE FACTORS OF WORKING CONDITIONS	**Epidemiologic indicators**		***% risk***	***P*** ***(χ^2)***	**Statistic significance of differences**
	Odds Ratio (OR)	**95% confidential limits**			
Repetitive work (Monotoneous)	**7.11**	**1.66 < OR < 30.22**	**92.75**	**0.0033**	**
Long persistence in the working position	*3.48*	*1.05 < OR < 10.83*	*92.74*	*0.0548*	-
Insufficient breaks(Time for relax)	*3.30*	*1.00 < OR < 10.24*	*92.68*	*0.0678*	-
Work after injury and during sickness	*2.99*	*0.84 < OR < 10.44*	*92.56*	*0.0994*	-
Microclimatic conditions	4.03	0.72 < OR < 20.54	91.48	0.1376	-
High work pace	2.76	0.72 < OR < 10.17	92.06	0.1624	-
Forced working positions	2.35	0.62 < OR < 8.55	91.86	0.2568	-
Quality of work organisation	2.24	0.60 < OR < 8.10	91.80	0.2928	-
Handling heavy materials (weight of load)	2.24	0.60 < OR < 8.10	91.80	0.2928	-
Quality of tools	2.19	0.63 < OR < 7.49	92.10	0.2717	-
Quality of instructions and training	2.02	0.58 < OR < 6.89	91.96	0.3375	-
Work above the head level	1.87	0.54 < OR < 6.36	91.81	0.4097	-
Work on the limit of physical and psychical possibilities	1.80	0.52 < OR < 6.11	91.74	0.4479	-
Handling small objects	1.51	0.44 < OR < 5.08	91.34	0.6552	-
Excessive bending forward and rotating trunk	1.30	0.36 < OR < 4.57	90.82	0.8768	-

2.3 "B" Company

"B" company performs in the area of development, manufacturing and sales of moulding technology. The company produces eccentric compactors with the molding force ranging from 100 kN to 1000 kN and accessories for forming machines. The compactors are designed for the cold moulding of

metallic materials. They allow the user a wide application of both manual operations and automated lines. Accessories for the compactors manufactured in the company accelerate the work cycle.

2.3.1 Characteristics of the examined set of employees in "B" Company

"B" Company currently employs 80 people. For the purposes of the cross-sectional ergonomic analysis, 45 employees were addressed. The completed 38 questionnaires represented a return rate of 84.44%. The respondents were divided into working groups A, B and C. Out of 40 employees, four were women and 36 men. A statistically significant difference was in the representation of men and women working in the observed group B (83.3% of men) and group C (100% of men).

2.3.2 Incidence, localisation and intensity of disorders and damages to the musculoskeletal system of employees in "B" Company

The incidence and intensity of musculoskeletal system (MSS) disorders indicate the presence of labour system deficiencies in terms of ergonomics and the influence of systematic risk factors of the long-term MSS damage and work-related excessive and unilateral exposure.

Figure 9 shows that the incidence of disorders in the monitored areas was manifested in 90.0% of respondents regardless of gender.

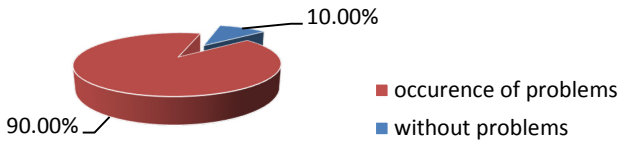


Fig. 9 *Incidence of MSS disorders of the examined employees in selected operations of "B"company*

Figure 10 documents the incidence of fatigue of all examined employees; 57.5% of them felt tired after a day of rest.

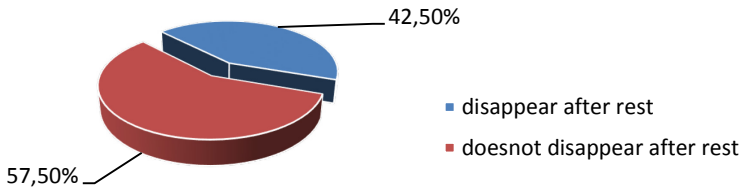


Fig. 10 *Incidence of symptoms and intensity of fatique of theexamined employees in selected operations of "B"company*

Up to 67.5% confirmed the occurrence of carpal tunnel syndrome (CTS), as shown in Figure 11.

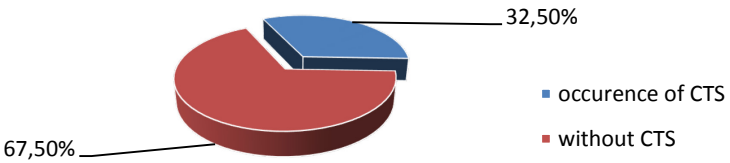


Fig. 11 *Incidence of symptoms of carpal tunnel syndrome (CTS) in the set of examined employees in selected operations of B Company*

Table 9 shows that the monitored employees regardless of sex in all the working groups experienced disorders in the lumbosacral (waist) spine as well as disorders in the ankles/feet and , hand/palms in the past year. All groups, however, reported the musculoskletal system disorders were localised in the areas of neck, hands, knees and feet, while most disorders were stated by the employees in a workgroup of machining.

INCIDENCE AND LOCALISATION OF MSS DISORDERS IN THE EXAMINED SET OF EMPLOYEES IN WORKING GROUPS

Table 9

LOCALISATION OF MSS DISORDERS	**Incidence and localisation of MSS disorders in working groups for the past year**			**TOTAL n = 38**
	A n = 8 (%)	**B n = 24 (%)**	**C n = 6 (%)**	
Neck	**62.5**[1)]	**58.3**[4)]	33.3	55.3%
Shoulders	25.0	45.8	16.7	36.8%
Back (thoracic region)	37.5	**66.7**[3)]	**50.0**[2)]	57.9%
Elbows	12.5	45.8	0.0	31.6%
Croup (lumbosacral region)	**62.5**[1)]	**87.5**[1)]	**66.7**[1)]	78.9%
Hands/wrists	25.0	**83.3**[2)]	**50.0**[2)]	65.8%
Hips/thighs	37.0	33.3	16.7	31.6%
Knees	**50.0**[2)]	**58.3**[4)]	33.3	52.6%
Ankles/Feet	**50.0**[2)]	**66.7**[3)]	**66.7**[1)]	63.2%

The highest intensity of MSS disorders requiring a doctor visit in the past year was stated in the area of loin, thoracic spine and neck. The working group A reported the intensity of such problems also in the area of the knees.

2.3.3 Selected symptoms and factors affecting the incidence and intensity of disorders and damage to the musculoskeletal system of employees in "B" Company

Table 10 documents the total score of modifiable factors of the work and working conditions in the monitored working groups as a percentage. The highest rating of the most negative factors in the table was identified by the staff working in group B.

Furthermore, the working groups identified a statistically significant difference in the incidence of CTS symptoms. The occurrence of these symptoms was statistically significantly highest in the working group B (80% of the symptom incidence). Relatively high values also occur in the case of group A (50% incidence of the symptom).

The incidence of MSS disorders in relation to fatigue in individual operations for the past year, which required a doctor visit, proved to be statistically significant. A doctor visit due to persistent fatigue was necessary in 100% of cases.

PERCENTAGE OF RESPONSES INDICATING THE GIVEN FACTOR AS A MAJOR PROBLEM (9 AND 10) ON A SCALE OF 1 - 10 OF THE QUESTIONNAIRE IN WORKING GROUPS OF "B" COMPANY

Table 10

FACTORS OF WORKING CONDITIONS	WORKING GROUPS			TOTAL n = 38
	A n = 8 (%)	B n = 24 (%)	C n = 6 (%)	
Repetitive and monotoneous work	0.0	37.5	0.0	26.3%
High working pace	0.0	**50.0**[3)]	0.0	34.2%
Handling small objects	0.0	8.3	0.0	5.3%
Insufficient breaks (Time for relax)	0.0	37.5	**33.3**[2)]	31.6%
Forced working positions	0.0	29.2	16.7	23.7%
Long persistence in a working position	0.0	**58.3**[2)]	0.0	39.5%
Excessive bending forward adn rotation of trunk	0.0	**50.0**[3)]	0.0	34.2%
Work above the limit of physical and psychical possibilities	0.0	37.5	16.7	26.3%
Work above the head level	0.0	33.3	16.7	26.3%
Microclimatic conditions	0.0	**70.8**[1)]	16.7	52.6%
Work after injury and during sickness	0.0	**45.8**[4)]	**33.3**[2)]	36.8%
Handling heavy material	0.0	**50.0**[3)]	16.7	39.5%
Quality of work organisation	0.0	41.7	**50.0**[1)]	39.5%
Quality of tools	0.0	33.3	0.0	21.1%
Quality of introductory instructions and training	0.0	12.5	0.0	7.9%

The following Table 11 illustrates the influence of modifiable factors of the work and working environment in the monitored working groups of employees. The order of modifiable factors was identified primarily based on the values of the "Odds Ratio" (OR) calculated in a retrospective cohort study.

The values of the "Odds Ratio" greater than zero indicates the frequency of MSS disorders and doctor visits due to the intensity of the above-mentioned disorders of the employees reporting the presence of the selected modifiable factor of labour and working conditions. The confidence limits

for the “Odds Ratio” were greater than zero, thus confirming also its statistical significance.

If it was not possible to calculate the “Odds Ratio”, a further criterion applied was the prevalence of the MSS disorders value for the given factor (the ratio of workers with MSS disorders in relation to all employees exposed to the modifiable factor).

2.4 “C” Company

“C” Company belongs to a multinational group which produces a wide-ranging portfolio of manufacturing bearing products for a various application areas. The catalogue of standard bearings contains over 40,000 types that are delivered to 60 various areas of industry. In addition, the company offers extensive services in the field of calculations, diagnostics, maintenance and assembly of rolling bearings and complex systems.

“C” Company operates in engineering production, dealing with the development, production and sales of the needle, roller and linear bearings, equipment and materials for the production of bearings as well as automotive components such as tooth wheels, gearings and control elements.

ASSESSING THE TOTAL NEGATIVE IMPACT OF MODIFIABLE FACTORS OF WORK AND WORKING ENVIRONMENT ON INCIDENCE OF MSS DISORDERS BY THE EMPLOYEES OF "B" COMPANY Table 11

MODIFIABLE FACTORS OF WORKING CONDITIONS	**Epidemiologic indicators**		***% risk***	***P*** (χ^2)	**Statistic significance of diferences**
	Odds Ratio (OR)	**95% confidential limits**			
Quality of tools	2.67	0.00 < OR < 47.87	91.43	1.0000	-
Quality of instructions and training	0.87	0.00 < OR < 11.85	89.66	1.0000	-
Long persistence in working position	0.00	0.00 < OR < 53.79	89.47	1.0000	-
High pace of work	0.00	0.00 < OR < 53.79	89.47	1.0000	-
Forced labour position	0.00	0.00 < OR < 14.05	88.57	1.0000	-
Repetitive and monotonous work	11.67	0.00 < OR < 635.24	92.11	0.1923	-
Work after injury and during illness	11.67	0.00 < OR < 635.24	92.11	0.1923	-
Handling heavy material (weight of load)	11.67	0.00 < OR < 635.24	92.11	0.1923	-
Excessive bending forward and rotation of trunk	5.67	0.00 < OR < 147.90	91.89	0.4270	-
Handling small objects	5.00	0.39 < OR < 68.03	93.75	0.1723	-
Quality of work organisation	3.67	0.00 < OR < 76.24	91.67	0.3554	-
Work at the limiting physical and mental possibilities	3.67	0.00 < OR < 76.24	91.67	0.3554	-
Working above the head level	2.67	0.00 < OR < 47.87	91.43	0.4270	-
Insufficient breaks (time to relax)	2.07	0.00 < OR < 33.78	91.12	0.4925	-
Microclimate			90.00		

2.4.1 Characteristics of the examined set of employees in "C" Company

The cross-sectional ergonomic analysis carried out in "C" Company involved 230 employees. 229 questionnaires were completed, representing a 99.56% return rate. To obtain the informed consent of the subjects examined

for inclusion into this study, “Information on filling in the questionnaire” was explained. Its objective was to inform potential participants about the objectives, importance and benefits of the study, their rights either not to participate or to participate anonymously, and the process of confidential distribution and collection of the questionnaires. For the purposes of analysis, the employees were divided into working groups A, B, C, D and E. The division of employees into working groups according to their profession is shown in Table 20. The total sample consisted of 229 employees, represented by 44 men and 185 women.

A statistically highly significant difference was shown in the representation of men and women in the observed working groups. The working groups identified as A and B consisted of 100% of women. Women markedly prevailed in the working group C. Representation of men and women did not differ significantly in the working group identified as D. The working group entitled E was the only one comprised of more men than women.

2.4.2 Incidence, localisation and intensity of disorders and damages to the musculoskeletal system of employees in “C” Company

The following figures illustrate localisation and intensity of the disorders and damage to the musculoskeletal system of employees.

Figure 12 illustrates that 92.6% of employees surveyed felt disorders associated with performing their work.

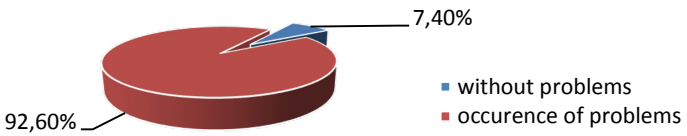


Fig. 12 *Incidence of MSS disorders of the examined employees in selected operations of "C" Company*

As can be seen in Figure 13, 34.1% of respondents had to visit a doctor due to the disorders of musculoskeletal system.

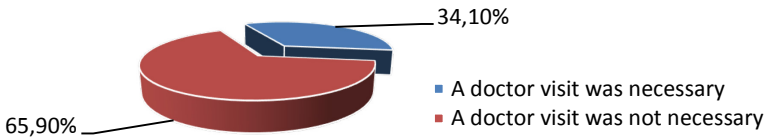


Fig. 13 *Doctor's visits due to the intensity of MSS disorders based on subjective references of the examined employees in selected operations of "C" Company for the past year*

As seen in the following two Figures 14 and 15, the incidence of carpal tunnel syndrome was reported in up to 54.6% of monitored workers, while 39.3% of them stated that fatigue due to work did not disappear, but persisted the day after.

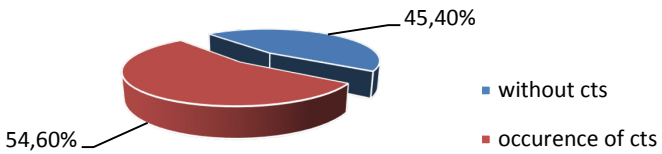


Fig. 14 *Incidence of CTS of the employees in selected operations of "C" Company*

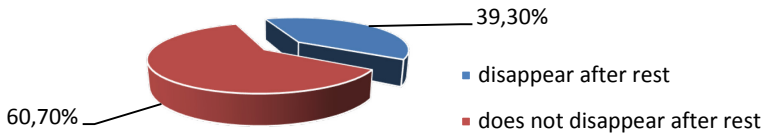


Fig. 15 *Total incidence and intensity of fatigue of the employees examined in the selected operations of "C" Company*

Table 12 reveals that all workers in the examined working groups regardless of their gender, in the past year described disorders of the thoracic and lumbar spine. Generally, however, there were also disorders of the musculoskeletal system localised in the neck, hands and feet.

A similar intensity of MSS disorders localised in the waist, back, neck and feet was reported in the working groups of packaging, assembly, maintenance and the assembly lines operation.

INCIDENCE AND LOCALISATION OF MSS DISORDERS
OF EXAMINED EMPLOYEES IN WORKING GROUPS Table 12

LOCALISATION OF MSS DISORDERS	**Occurrence and localisation of MSS difficulties in working groups within the past year**					**TOTAL n = 229**
	A (n = 15)	**B** (n =19)	**C** (n = 127)	**D** (n = 52)	**E** (n = 15)	
Neck	**33.3**[3)]	**63.2**[2)]	**55.1**[4)]	**47.2**[3)]	26.7	50.7%
Shoulders	20.0	**42.1**[5)]	38.6	28.3	33.3	34.9%
Back (thoracic region)	**53.3**[1)]	**63.2**[2)]	**64.6**[1)]	**43.4**[4)]	**40.0**[3)]	57.2%
Elbows	6.7	**47.4**[4)]	15.7	15.1	6.7	17.0%
Croup (lumbosacral region)	**46.7**[2)]	**57.9**[3)]	**58.3**[2)]	**49.1**[2)]	**53.3**[1)]	55.0%
Hands/wrists	**26.7**[4)]	**73.7**[1)]	**56.7**[3)]	**39.6**[5)]	26.7	50.2%
Hips/thighs	6.7	10.5	16.5	22.6	6.7	16.2%
Knees	**26.7**[4)]	21.1	31.5	30.2	26.7	29.7%
Ankles/Feet	**46.7**[2)]	36.8	**47.2**[5)]	**54.7**[1)]	**46.7**[2)]	48.0%

As seen in Table 12, the highest intensity of MSS disorders requiring a doctor visit within the past year was reported in the area of the waist. In the working group C, a high intensity of disorders occurred also in the neck and back. The working group B stated the incidence of disorders throughout the upper body with the highest intensity in the waist and neck, requiring a doctor visit. The working group E encountered the most common disorders in the lower back, knees and feet. Again, the highest intensity requiring a doctor visit was identified in the back.

The results obtained indicate a statistically significant difference in the incidence of MSS disorders in the working groups (Table 13) B, C, D and E.

INCIDENCE AND LOCALISATION OF MSS DISORDERS
OF EXAMINED EMPLOYEES IN WORKING GROUPS Table 13

WORKING GROUPS	OCCURENCE OF MSS disorders				TOTAL	
	Occurrence of disorders		Without disorders			
	frequency	%	frequency	%	frequency	%
A	11	73.3%	4	26.7%	15	6.6%
B	**19**	**100.0%**	0	0.0%	19	8.3%
C	**120**	**94.5%**	7	5.5%	127	55.5%
D	**48**	**90.6%**	5	9.4%	53	23.1%
E	**14**	**93.3%**	1	6.7%	15	6.6%
TOTAL	212	92.6%	17	7.4%	229	100.0%

Expected value < 5 occurs, and therefore Chí quadrat is not valid

Chí quadrat = 10.61

Number of degrees of freedom = 4

Probability "p" = **0.0314***<---

2.4.3 Selected symptoms and factors affecting the incidence and intensity of disorders and damage to the musculoskeletal system of employees in "C" Company

Table 14 documents the total score of modifiable factors of work and working conditions in the monitored working groups as a percentage. The evaluation comprises only the percentage of the assessment expressed by marks 9 and 10 on the scale of 1-10. A maximum of 5 factors with the highest rating is highlighted in the columns showing the evaluation of work and working conditions. The Table shows that the most negative factors with the highest rating were identified by the staff in the working group A; least factors were indicated in the working group E.

A statistically significant difference was determined in the CTS incidence in working groups. Occurrence of the syndrome is significantly highest in the working group B (73.7% of symptoms); it was high also in the working groups D (59.1% of symptoms) and A (53.3% of symptoms).

PERCENTAGE OF RESPONSES INDICATING THE GIVEN FACTOR AS THE KEY PROBLEM (9 AND 10) ON THE SCALE 1 - 10 OF THE QUESTTIONNAIRE IN THE WORKING GROUPS OF "C" COMPANY Table 14

FACTORS OF WORKING CONDITIONS	OBSERVED WORKING GROUPS					TOTAL (n =229)
	A (n = 15)	B (n = 19)	D (n = 53)	C (n =127)	E (n = 15)	
Microclimate	**53.3%[1)]**	**21.1%[3)]**	**32.1%[1)]**	**22.8%[2)]**	**20.0%[2)]**	26.6%
Long persistance in working position polohe	**33.3%[4)]**	**31.6%[1)]**	**28.3%[2)]**	**22.0%[3)]**	6.7%	24.0%
Handling heavy material	**33.3%[4)]**	**21.1%[3)]**	**18.9%[4)]**	**26.0%[1)]**	6.7%	23.1%
High pace of work	13.3%	15.8%	**17.0%[5)]**	**26.0%[1)]**	6.7%	21.0%
Qualityof work organisation	**33.3%[4)]**	**26.3%[2)]**	**20.8%[3)]**	**19.7%[5)]**	**26.7%[1)]**	21.8%
Insufficient breaks (Time for relax)	**46.7%[2)]**	**21.1%[3)]**	9.4%	**20.5%[4)]**	0.0%	18.3%
Work after injury and sickness	**33.3%[4)]**	10.5%	15.1%	18.1%	13.3%	17.5%
Work at the limiting possibilities	**40.0%[3)]**	15.8%	15.1%	13.4%	**20.0%[2)]**	16.2%
Excessive bending forward and rotation of trunk	**33.3%[4)]**	5.3%	11.3%	15.0%	6.7%	14.0%
Quality of tools	20.0%	10.5%	11.3%	9.4%	0.0%	10.0%
Forced working positions	6.7%	5.3%	7.5%	8.7%	0.0%	7.4%
Repetitive and monotoneous work	6.7%	5.3%	3.8%	7.9%	0.0%	6.1%
Quality of instructions and training	13.3%	5.3%	9.4%	3.1%	0.0%	5.2%
Handling small objects	0.0%	0.0%	1.9%	4.7%	6.7%	3.5%
Work above the head level	13.3%	0.0%	7.5%	5.5%	0.0%	5.7%

In total and disregarding gender and working groups, the following modifiable factors statistically significantly contribute to the incidence of MSS disorders: **"Repetitive work", "Quality of work organisation", "Work after injuries and illness", "Handling small objects" and "Insufficient breaks"** (Table 15).

ASSESSING THE TOTAL NEGATIVE IMPACT OF MODIFIABLE FACTORS OF WORK AND WORK ENVIRONMENT BY THE EMPLOYEES OF "C" COMPANY ON THE INCIDENCE OF MSS DISORDERS Table 15

MODIFIABLE FACTORS OF WORKING CONDITIONS	**Epidemiologic indicators**		**% risk**	**P (χ^2)**	**Statistic Signifi-cance of differences**
	Odds Ratio (OR)	**95% confidential limits**			
Repetitive and monotonous work	**9.19**	**2.54 < OR < 30.98**	**95.2**	**0.0003**	***
Quality of work organisation	**6.36**	**1.99 < OR < 20.30**	**95.4**	**0.0010**	***
Work after injury and during illness	**5.08**	**1.56 < OR < 17.49**	**96.6**	**0.0032**	***
Handling small objects	**3.31**	**1.04 < OR < 10.35**	**94.6**	**0.0256**	*
Insufficient breaks (time to relax)	**2.96**	**0.97 < OR < 9.02**	**94.8**	**0.0397**	*
Quality of instructions and training	*3.13*	*0.97 < OR < 10.71*	*96.0*	*0.0557*	-
Work at the limiting physical and mental possibilities	*2.92*	*0.97 < OR < 8.88*	*95.2*	*0.0569*	-
Excessive flexion forward and rotation of trunk	*2.88*	*0.94 < OR < 8.77*	*94.7*	*0.0640*	-
Quality of tools	*2.72*	*0.90 < OR < 8.27*	*94.9*	*0.0784*	-
Long persistence in working position	2.30	0.57 < OR < 8.53	93.5	0.2435	-
High pace of work	2.22	0.22 < OR < 11.45	93.0	0.6279	-
Working above the head level	2.18	0.71 < OR < 7.00	94.8	0.1963	-
Handling heavy material (weight of load)	2.11	0.54 < OR < 6.92	93.7	0.1874	-

2.5 Summary of the current state of ergonomics implementation in business logistics

The aim of the survey carried out was to assess the implementation of ergonomics in business logistics through tracking the employees' complaints about MSS disorders. The incidence and intensity of MSS disorders in the monitored enterprises documented the gaps in terms of ergonomics. The ergonomic solution is based on the assumption that high quality work performance can be expected only from the healthy, rested and satisfied employees. For employers, the importance of ergonomics lies in the fact that it contributes to sustainable business competitiveness via improving the effectiveness of human labour while avoiding the health damage of employees and simultaneously achieving economic benefits.

Ergonomic analysis was based on the data obtained in the selected business companies designated as "A", "B" and "C" from 418 respondents, which represents **97.21%** of the total number of 430 addressed employees.

In "A" Company, MSS disorders as a major indicator of the workplace deficiencies in terms of ergonomics generally occurred in **90.10%** of all surveyed employees. Similar results can be observed in the case of "B" and "C" Companies, where MSS disorders were encountered in **90.00% and 92.60%** of all employees surveyed. Based on these results, 2/3 of employees confirmed the postulated hypothesis regarding the incidence of MSS disorders.

It was due to the intensity of these disorders in the past year that **28.90%** of the employees for "A" Company, **34.10%** of employees of C Company and up to **45.00%** of the employees of "B" Company had to see a doctor. The

data collected by the questionnaire survey confirmed the second hypothesis, which predicted the necessity of medical assistance due to the incidence of MSS disorders in **25%** of employees.

In the chosen companies, all the 15 selected factors of work and work environment contributed to MSS disorders. This was confirmed by the third hypothesis regarding the impact of factors, while a statistically highly significant one in "A" Company was identified as **repetitive and monotonous work**.

Emerging trends can be observed in the following factors:

- ***long persistence in a working position,***
- ***insufficient breaks (time for relax),***
- ***work after injury and during sickness.***

None of the observed modifiable factors showed a statistically significant difference in "B" Company; i.e. each of the 15 surveyed factors was involved in causing disorders and damage of the MSS of employees.

Statistically highly significant factors in "C" Company were as follows:

- ***repetitive and monotonous work,***
- ***quality of work organisation,***
- ***work after injury and during sickness.***

Other statistically highly significant factors were:

- ***handling small objects,***
- ***work after injury and during sickness.***

An indication of emerging trends were observed in the following factors:

- ***quality of instructions and training,***
- ***work on the level of physical and psychical possibilities,***
- ***excessive flexion forward and rotation of trunk,***
- ***quality of tools.***

Based on the results of the presented ergonomic analysis of workplaces in the areas of supply, storage, production, factory transport and distribution in selected companies we can state the gaps in terms of ergonomics. Failure in the implementation of appropriate preventive measures may gradually grow into clinical manifestation of the encountered MSS disorders.

We can generally state that the findings confirm the hypothesis regarding the excessive and systematic impact of risk factors of MSS disorders due to work-related long-term excessive unilateral exposure. It is necessary therefore to introduce effective preventive measures in the examined workplaces.

3. ERGONOMICS IMPLEMENTATION IN BUSINESS LOGISTICS

Building suitable working conditions is one of the basic prerequisites for successful performance of a company. Employees represent one of the main pillars of any industrial enterprise. If working conditions assure the minimum impact of risk factors, employees will be able to deploy their full working capacity, which consequently assures sustainable competitiveness of a company.

The survey results showed some deficiencies in the application of ergonomics in the performance of the staff directly involved in logistics operations. These shortcomings ultimately affect the time and quality, as well as the economic aspect of work activities.

Based on the survey results, the author of this monograph designed a procedure for the implementation of ergonomics in business logistics, allowing the companies to introduce certain rationalisation measures aimed at minimising the impact of risk factors on employees, and more efficient utilisation of the employees' potential along with reduced workload.

3.1 Theoretical background of the solution

This chapter briefly describes the issue of increasing the efficiency of human labour by minimising the negative impact of modifiable and unmodifiable factors on employees.

3.1.1 Research focus

Business logistics is a system of tangible and intangible flows, which, on the level of material flows and performed logistics operations, represents a typical man-machine-working environment system with the direct participation of employees performing work activities.

Increasing the efficiency of human labour and logistics processes through the implementation of ergonomic solutions, where employees are exposed to risk factors that adversely affect the musculoskeletal system, in business logistics is generalised in this monograph, to the level of implementation of logistics operations actively involving all employees, i.e. where the work activities directly affecting the formation of disorders and damage of musculoskeletal system are performed. The musculoskeletal system represents a major limiting factor of job performance and efficiency of the performed business activities.

Regarding the above-mentioned, this monograph is devoted to the methodology of the improvement of working activities with the aim of reducing the load on the musculoskeletal system of employees along with the personnel, organisational, technical and financial assurance.

3.1.2 Load parameters of the musculoskeletal system of employees

Adjustment of work to each individual and search for the balance between the options of employees' performance and demands for work activities are two essential tasks in ergonomics. The survey results confirmed that it is often very difficult to achieve the balance; its absence results in excessive loading of the employees' musculoskeletal system.

Load of the musculoskeletal system can be characterised by monitoring the basic ergonomic parameters, which include:

- ***time & movements,***
- ***space & strain.***

Time

Time is the most exactly quantifiable parameter of the working process, which can express the load of the musculoskeletal system of employees and economic efficiency of work. The musculoskeletal load of employees is frequently caused by the factor of time giving rise to fatigue due to uninterrupted work operation, work monotony, absence of micro pauses etc.

Movements

Movement is a parameter influenced by two factors. The first factor is the workspace, which affects the range of motion on the one hand, and also limits the movements of employees in the performance of work activities, on the other hand. The second factor is the actual movement performed by the employees based on their own capabilities, experience, completed training, etc.

Space

The parameter of space is the factor that determines the degrees of freedom of workers' movement, while respecting the anthropometric dimensions of the human body. Optimum dimensions of the manipulation and pedipulation space should allow the implementation of the minimum length and optimum paths of movements.

Strain

Strain is the response of an organism to the load due to the work-related activities of employees. It is characterised by the changes in parameters of physiological functions involved in the body organ systems. In general, this means the accommodative response and associated changes. When evaluating strain at work, it is important to monitor the parameters related to energy expenditure (e.g. heart rate, breathing characteristics etc.).

3.1.3 Quantification of load parameters of the employees' musculoskeletal system

The previous section briefly defined the loading parameters of the musculoskeletal system of employees. This section presents the possibilities for their quantification.

As mentioned above, the time factor is an exact parameter quantifiable by a set of methods of time studies applicable in ergonomic analysis:

- ***time studies of an operation*** - chronometry, multiple activity shot, a film shot,
- ***time studies of a workday*** – workday shot of an individual, workday shot of a team, cumulative workday shot of operating more machines.

The parameter of movement can be tracked and quantified using a number of methods such as:

- ***micromovement studies*** - film recording, methods of predetermined time standards,
- ***studies of movement paths*** – cyclography, chronocyclography.

The parameter of space which must respect the anthropometric dimensions of employees can be determined by calculating:

- ***production area*** - the area of the machinery, manual and small maintenance workshops
- ***storage area***,
- ***auxiliary area*** – the area of transport routes, auxiliary departments,
- ***administration area***,
- ***social area*** – washrooms, changing rooms, toilets, restrooms.

The parameter of strain characterising the response of an organism to the load of an employee's musculoskeletal system can be quantified by means of the energy expenditure, using the following methods:

- ***indirect calorimetry*** - the principle of determining the oxygen needs of an individual,
- ***table values of energy consumption*** - table values of a minute energy expenditure for various tasks, work operations and acts,
- ***calculation of labour energy consumption according to the position and movement of the body (walking) and means of performing work*** - assumes that the body posture at work affects metabolism while increasing the muscle tonus and contraction.

3.2 Ergonomic aspects of improving working activities in order to reduce the load on the musculoskeletal system of employees

A combination of an ergonomic programme and the Kaizen philosophy was used as a support tool for the development of suitable working conditions with the aim to reduce the load on the musculoskeletal system of employees.

The steps of the resulting support process of the ergonomic solution are described in detail in the following chapters.

Kaizen generally means continuous improvement in small steps via the introduction of slow changes in a non-disruptive way. Kaizen can help to assure sustainability of the current technological standards, create optimum working conditions, maintain a high level of knowledge and education of employees, as well as increase technology standards, working conditions, health of workers and the level of knowledge and education. To do so it is appropriate to utilise the PDCA cycle aimed at the process of improvement. Ergonomic programmes focus on human work efficiency via minimising the negative impacts on health, while simultaneously maximising economic benefits. Ergonomic programmes are typified by their approach, i.e. continuous approximation to the achievement of goals, such as setting the optimum working conditions, environmental conditions, setting the machines and relations in the man-machine-working conditions and organisational system.

In the case of unsuitable workplace conditions, increased accident and illness rates and fluctuation of employees in the workplace; managers and ergonomists should start searching for the causes of the problems and then implement the measures ensuring their elimination.

We developed a modification of the process of identifying an ergonomic solution within the ergonomics programmes in interaction with the PDCA cycle, which appears to be an effective tool for the corrective measures implementation. It is illustrated in the following two Figures 16 and 17.

Fig. 16 *General model of the process of ergonomic solution*

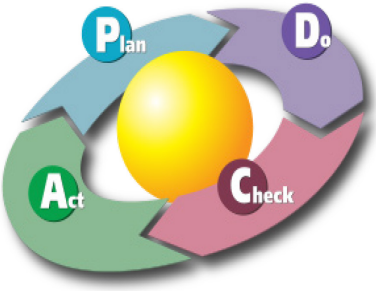


Fig. 17 *Basic PDCA cycle (50)*

The course of the PDCA cycle remains unchanged in the designed modification. The first stage - Planning is followed by the stages of Implementation, Check and Action. The original five steps of the general process model of ergonomic solutions were enhanced by the sixth one. The process of ergonomic solutions in the course of the PDCA cycle is carried out in four phases. The support process of ergonomic solution is illustrated in Table 16.

SUPPORT PROCESS OF ERGONOMIC SOLUTION Table 16

Support process of ergonomic solution			
	Main stages	**Activities**	**Specification of activity**
P	**PROBLEM IDENTIFICATION AND ANALYSIS OF CAUSES OF THEIR INCIDENCE**	➢ development of databasis ➢ analysis	➢ using databasis – analytical application of Ergo&Log© ➢ analysis by using 2M2W tool
	SETTING OBJECTIVES	➢ setting objectives from the point of business logistics ➢ setting ergonomic objectives	➢ specification of objective ➢ determining indivators ➢ feasibility of objective ➢ relevancy of objective ➢ deadline for objective
D	**DESIGN OF RACIONALISATION OF ERGONOMIC MEASURES**	➢ designing racionalisation measures	➢ collecting basic facts ➢ defining basic work elements ➢ measuring and graphical expression of of the work elements' duration ➢ analysis of options, possible solutions ➢ eliminating the working process elements and work environment parameters affecting the incidence of disorders and troubles of musculoskeletal system of employees ➢ optimum arrangements of the elements of work process and setting up the parameters of work environment into a functional state ➢ adopting a new concept of skills ➢ building self-discipline
	TESTING THE DESIGNED RACIONALISATION MEASURES IN REAL CONDITIONS	➢ testing corrective measures associated with vizualisation of proposals	➢ setting up the objective of visualisation ➢ determining the contents of visualisation ➢ specififying the means of visualisation ➢ defining responsibilities for the implementation of visualisation
C	**CHECK AND EVALUATION OF EFFECTS OF THE DESIGNED RACIONALISATION MEASURES**	➢ continuous check ➢ final check	➢ controlled dialogues ➢ videoanalysis ➢ comparing the palnned status with the real achieved one
A	**DEVELOPMENT OF ERGONOMIC STANDARDS FOR THE DESIGNED MEASURES**	➢ developing standards based on the previous steps for the improvement of the starting status	➢ developing an ergonomic standard ➢ preparation of information material ➢ visualisation of standards and staff training ➢ implementation and inspection of the standard observance ➢ improvement of standard
	REVISION OF THE PREVIOUS CYCLE	➢ carrying out revision in case of failure of implementation of the support process of ergonomic solution	➢ revision of the previous cycle ➢ utilising feedback to identify failure

Conditions of the working environment and work activities of employees existing at the beginning of the support process of ergonomic solutions should be considered standard for a particular company and given initial situation.

3.2.1 Identification of problems and analysis of their causes

Phase 1 in the implementation of the support process of ergonomic solution is the analytical one, consisting of two steps: step 1 – problem identification and analysis of its cause, and step 2 - setting objectives.

Identification of the emerging or persistent problems of employees is based on the suggestions from line managers who are directly informed by employees. Problems of employees may result in complaints about pain and numbness, increased staff turnover and absenteeism, increased accident rate in the performance of individual operations, increased production of scrap and defect rate in check-in and check-out etc. Identification of the factors indicates the deficiencies in the man-machine-working environment system.

Subsequent analysis of its root cause specifies the problem. The implementation of ergonomic analysis can be carried out in two ways.

The first method is an analysis that can be carried out by experts in the field of ergonomics, particularly by means of the co-operation with an external company, and subsequent statistical evaluation of the impact of modifiable and unmodifiable factors on the occurrence of disorders and damage to the health of employees. The initial analysis takes the form of a retrospective cohort study; the subsequent repeated analysis is then a cohort study.

The other technique is the proposed method of implementation of ergonomic analysis at the enterprise level, using several tools allowing the definition and specification of the problem, and also to determine its root cause. A variety of ergonomic checklists and questionnaires and also video recordings for subsequent analysis of the entire system can be used to reveal the cause of the problem occurring in the man-machine-working environment system.

Various tools can be used in the implementation of an analysis in the area of business logistics, such as the database-analytical applications of Ergo & Log and 2M2W tools.

Databases and analytical application of Ergo&Log©

Successful implementation of the support process of an ergonomic solution in a company requires a database of employees, which would enable a quick ergonomic analysis.

To support the successful implementation of an ergonomic solution in the analytical phase, we designed and elaborated a database - Ergo & Analytical Application Log. This pilot project will help to explain the databases of employees and provide the possibility of implementing fast and accessible ergonomic analyses.

The application was developed by using the scripting programming language PHP, MySQL database and the Apache Web server application. The application requires an in-house server allowing access to the Intranet and Internet, and allows its users to view the current legislative and normative regulations in terms of ergonomics and work safety. The following pages

show an example of using the Ergo & Log database program supported by screenshots of the application.

In the first step, the administrator develops a database of employees, as illustrated in Figure 18. Employees are divided into predefined areas in which they operate, e.g. supply, production, storage and commissioning, factory transport, material flow and distribution, as shown in Figure 19.

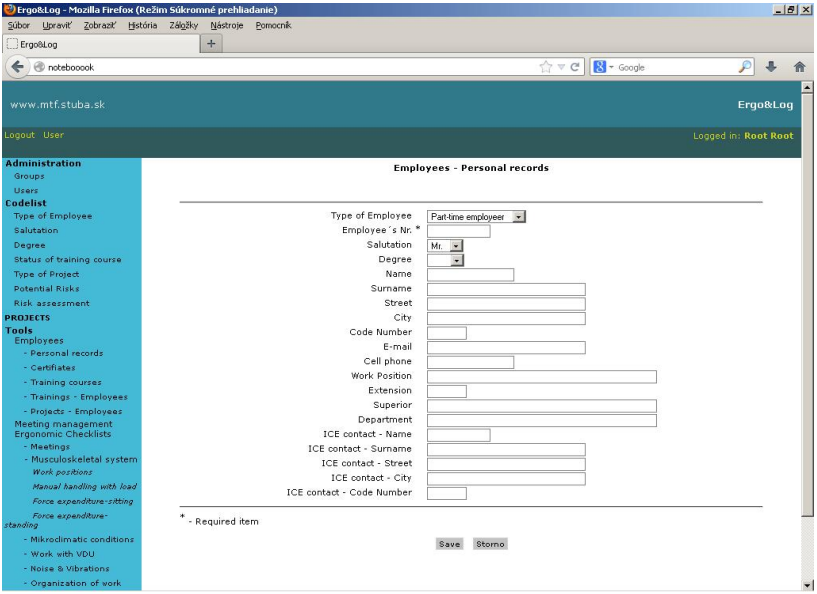


Fig. 18 *Database of employees*

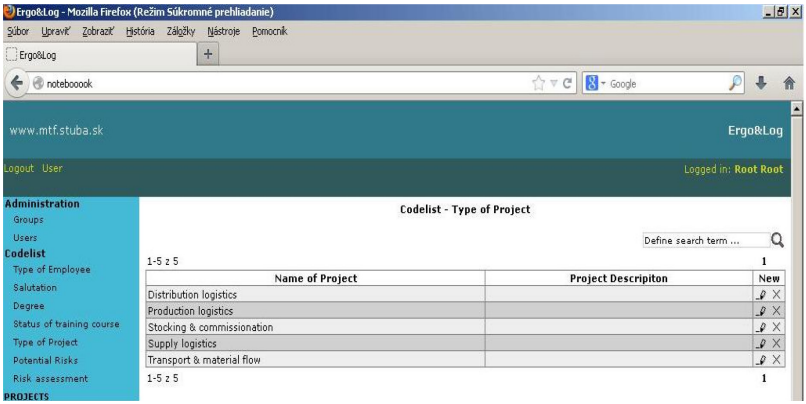


Fig. 19 *Projects from the overlapping areas of business logistics*

Every employee creates a specific account (Figure 20), where s/he fills in a pre-defined checklist, as determined by the application administrator. After filling in the checklists, the employees evaluate the resulting output, as shown in Figures 21 and 22. The output can be then used for a more detailed analysis of the causes identified by means of the 2M2W analytical tool.

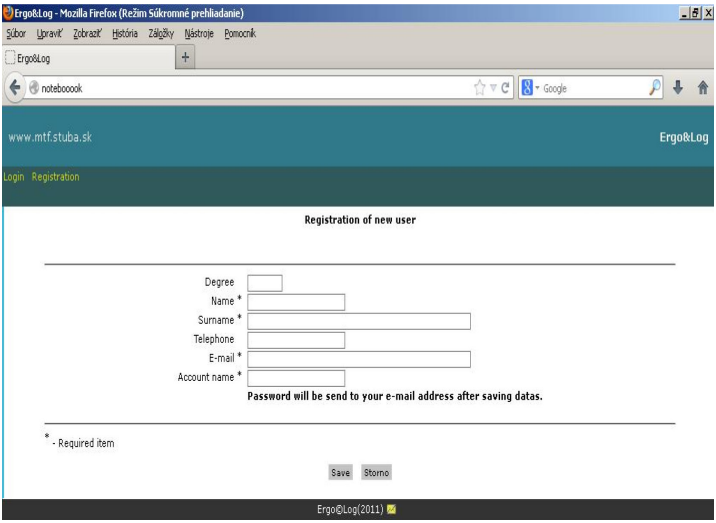


Fig. 20 *User's account*

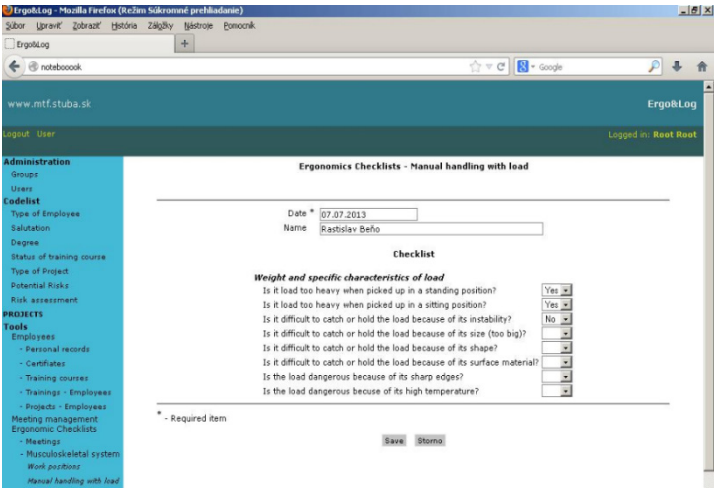
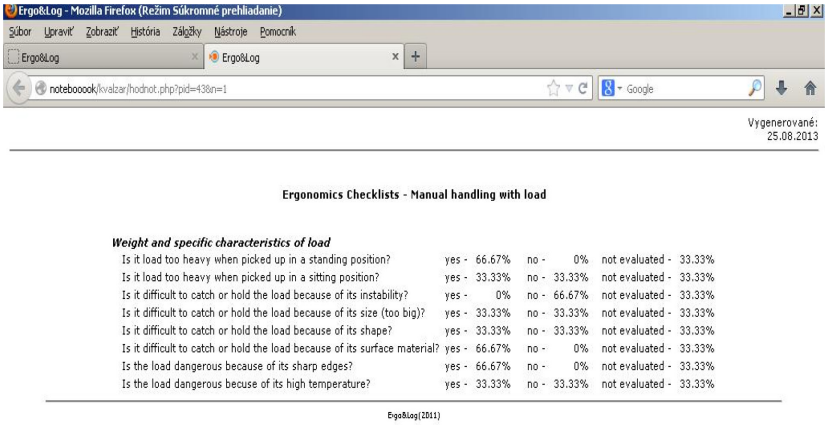


Fig. 21 *An example of filling in the checklist for the field of handling loads manualy*



Ergo&Log - Mozilla Firefox (Režim Súkromné prehliadanie)

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Ergo&Log | Ergo&Log

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Vygenerované: 25.08.2013

Ergonomics Checklists - Manual handling with load

Weight and specific characteristics of load

Is it load too heavy when picked up in a standing position?	yes - 66.67%	no - 0%	not evaluated - 33.33%
Is it load too heavy when picked up in a sitting position?	yes - 33.33%	no - 33.33%	not evaluated - 33.33%
Is it difficult to catch or hold the load because of its instability?	yes - 0%	no - 66.67%	not evaluated - 33.33%
Is it difficult to catch or hold the load because of its size (too big)?	yes - 33.33%	no - 33.33%	not evaluated - 33.33%
Is it difficult to catch or hold the load because of its shape?	yes - 33.33%	no - 33.33%	not evaluated - 33.33%
Is it difficult to catch or hold the load because of its surface material?	yes - 66.67%	no - 0%	not evaluated - 33.33%
Is the load dangerous because of its sharp edges?	yes - 66.67%	no - 0%	not evaluated - 33.33%
Is the load dangerous becuse of its high temperature?	yes - 33.33%	no - 33.33%	not evaluated - 33.33%

Ergo&Log(2011)

Fig. 22 *An example of evaluating the filled-in checklists of employees in Ergo&Logapplication*

Analytical tool 2M2W

Another possible analytical tool for a detailed analysis of the causes of the identified problem is the 2M2W analytical tool. The acronym for the tool 2M2W is derived from the English word man, machine, working environment and work organisation.

The tool works on the assumption that the cause of the problems can be sought in all the above-mentioned areas, while each of the selected areas is responsible for the indication of the defined problem to some extent. Figure 23 illustrates how all the elements, i.e. man, machine, working conditions and work organisation are involved in causing the MSS disorders due to the impact of risk factors in terms of ergonomics. The impact of the problems on the employees' MSS is determined by specific circumstances in each company. The Figure also shows the overlapping areas of the work organisational system.

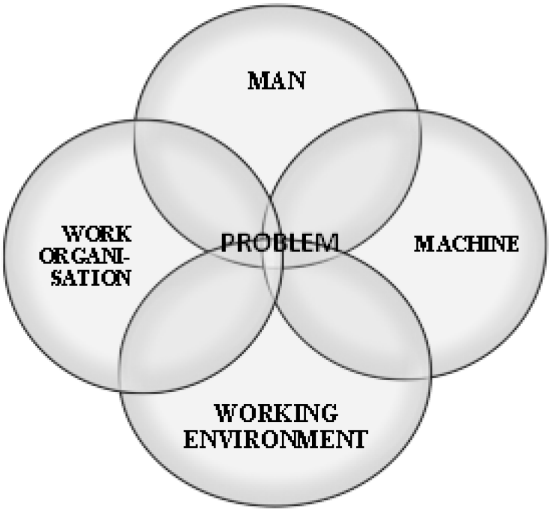


Fig. 23 *Impact of the working cycle elements on the incidence of employees' problems*

The procedure for using the 2M2W analytical tool consists of the following steps:

- ***Step 1: the basic critical factors affecting the formation of the identified problem are defined.***

  The number of critical factors in each observed area should be about the same in order to add prediction value to the analytical tool 2M2W. Examples of the selected critical factors for individual sub-systems of the work-organisational system are illustrated in Table 16.

- ***Step 2: individual critical factors are quantified using a numerical scale ranging from 1 – 4.***

  Each selected critical factor is assigned a value (mF) 1 to 4 based on the stress induced by the given factor. Individual values correspond to the following levels of stress (1 - no stress, 2 - low stress, 3 - high stress, 4 - cardinal stress). Consequently, in order to assure objectification of assessment, each critical factor was allotted a significance of impact. When assigning significance to assess the factor impact, individual factors are assessed in pairwise comparisons by using the Fuller triangle method.

Pairwise comparison of factors

Critical factor	**Critical factor**				**Number of votes allotted to a criterion**
1 redundant movements – rotation of the torso	1	1	1	1	3
	2	3	4	5	
2 height of the handling spot		2	2	2	2
		3	4	5	
3 necessity to walk a long distance with the carried load			3	3	2
			4	5	
4 long reaching distanced				4	1
5 missing auxiliary equipment for lifting objects				5	2

- ***Step 3: based on the votes allotted to each, the factor score of significance is determined as a ratio of the number of votes allotted by the i-th evaluator to the total number of evaluators.***

  Subsequently, the significance of the factor impact is calculated as a ratio of the factor significance value to the total sum of values of the monitored factors. To facilitate the evaluation, the values of HDF_j and h_F HDF_j are expressed in Table 17.

Score of the factor significance:

$$HDF_j = \frac{\sum_{i=1}^{P} PHij}{p} \qquad [1]$$

where:

HDF_j – value of significance of the j-th factor

PH_{ij} – number of votes alloted by the i-th evaluator to the j-th factor

p – number of evaluators participating in the process of evaluation

Significance of the factor impact:

$$h_F = \frac{HDF_j}{\sum_{j=1}^{m} HDF_j} \qquad [2]$$

where:

h_F –significance of the factor impact

m – number of factors

$\sum HDF_j$ – score of all critical factors m

DETERMINING THE SIGNIFICANCE OF THE FACTOR IMPACT

Table 17

Evaluator (i)	**(1) Excessive movements – rotation of the torso**	**(2) Height of the handling spot**	**(3) Necessity to walk a long distance with the corried load**	**(4) Long reaching distances**	**(5) Missing Auxilliary equipment for lifting loads**	**Σ**
	PH	PH	PH	PH	PH	PH
1	3	2	2	1	2	10
2	4	2	1	2	1	10
3	1	1	2	3	3	10
4	2	3	3	1	1	10
5	3	2	3	1	1	10
Σ	13	10	11	8	8	50
HDF	2.6	2	2.2	1.6	1.6	50
h_F	**0.26**	**0.2**	**0.22**	**0.16**	**0.16**	**1**

- ***Step 4: the resulting value of the critical factor is calculated in each monitored area***

  (man-machine, man-working environment and man-work organisation), as the product of scoring a critical factor and the significance of the given factor impact on the problem identified:

$$HKF = h_F \times m_F \qquad [3]$$

where:

HKF – value of critical factor

h_F – significance of the factor impact

m_F – value of factor [1 – 4]

- ***Step 5: the final step is calculating the sum of the critical factors values for each area of business logistics based on the total value of the sum of the critical factors values for all areas of business logistics.***

  Mathematically, it is also possible to express such evaluation as follows:

$$CKF = \frac{\sum HKF_{OL}}{\sum HKF} \times 100\,(\%) \qquad [4]$$

where:

CKF – total value of critical factors for the selected area of business logistics

HKF_{OL} – sum of the values of critical factors for the selected area of business logistics

HKF – sum of the values of critical factors for all areas of business logistics

Application of the 2M2W tool may involve a certain degree of error and inaccuracy due to purposive distortion of data by employees. When evaluating the identified critical factors, employees may act subjectively, which can subsequently lead to a decrease in the perception of objective reality. It is therefore appropriate to support the results provided by the analytical tool by using additional software tools of multicriteria decision-making. One of such tools offering the possibility of objectification is the free Expert Choice software. The product was developed in collaboration with Professor Saat of the Warton School of Business, University of Pennsylvania, USA.

ERGONOMIC FORM 2M2W Table 18

ERGONOMIC FORM 2M2W				
Identified problem:	Pain in lumbosacral part of spine			
Area of business logistics:	Supply logistics			
Field of ergonomic solution:	Musculoskeletal system			
Date and time:	DD. MM. RRRR			
	Critical factors	**Value of factor**	**Significance of the factor impact [h_f]**	**Value of critical factor [HKF]**
MAN - MACHINE	➢ redundant movements– rotation of trunk.	4	0.26	**1.04**
	➢ height of handling spot,	3	0.2	0.6
	➢ necessity to walk long distance with carried load,	3	0.22	0.66
	➢ long reaching distances,	2	0.16	0.32
	➢ missing auxiliary equipment for lifting loads.	2	0.16	0.2
MAN - WORKING ENVIRONMENT	➢ influence of vibrations,	2	0.197	0.394
	➢ strong air convection,	4	0.155	0.62
	➢ cold air,	3	0.368	1.104
	➢ insufficient PPE from the influence of microclimatic conditions.	4	2.280	**1.12**
MAN - WORK ORGANISATION	➢ insufficient introductory instructions	4	0.267	1.068
	➢ long-term performance of monotonous work,	4	0.386	**1.544**
	➢ low rotation of employees,	4	0.112	0.448
	➢ unsuitable distribution of breaks.	3	0.235	0.705

COMPARISON OF THE TOTAL VALUES OF CRITICAL FACTORS Table 19

Area of business logistics	Critical	Sum of critical factor values in the selected areas of business logistics [HKF_{OL}]	Sum of critical factor values [HKF]	Total values of critical factors [CKF %]
Supply	Redundant movements etc.	4.876	35.451	13.754
Storage and commissioning	Unsuitable handling level etc.	10.364	35.451	29.234
Production	Long reaching distances etc.	5.986	35.451	16.885
On site transportation and material flow	Monotonous work etc.	7.679	34.451	21.660
Distribution	Low rotation of employees etc.	6.546	35.451	18.464

3.2.2 Setting the objective

Having completed the analysis, it is necessary to determine the ultimate objective to be achieved, which thereby determines other attributes of the support process of ergonomic solution.

The determined objective must be specific and clearly defined, identifying what the company wants to achieve through the solution in a given situation. It should be based on the objective, real working conditions and working environment.

The achieved results must be measurable in two areas. The first area is ergonomics, where economic effect is frequently difficult to be quantified. The other area is business logistics, where effectiveness of the implemented operations and processes can be easily quantified.

The choice of indicators may be a matter of the individual company. Based on this assumption, the following three Tables 20, 21 and 22 list the recommended indicators that can be used to assess the achievement of an ergonomic solution's objective, both in terms of ergonomics and business logistics. This recommended set may be supplemented by other indicators, depending on individual circumstances and the impact of internal and external factors acting within the company.

The company must be able to determine the significance of individual indicators, set up time horizons for the monitoring and evaluation of indicators, and determine their limits, sources of information as well as the methods of their monitoring and evaluation.

SYSTEM OF RECOMMENDED ERGONOMIC INDICATORS

Table 20

System of recommended ergonomic indicators	
Indicators of productivity	➢ value added work, ➢ work productivity of employees, ➢ degree of intensity of employees' utilisation.
Indicators of impact on health of employees	➢ incident rate of employees, ➢ fluctuation of employees, ➢ sicknesss rate, ➢ prevalence, ➢ incidence, ➢ defectiveness and scrap rate.
Indicators of impact on the amount of costs	➢ costs for sick leave, ➢ costs for incident rate, ➢ costs for introductory instructions for employees, ➢ costs for courses ad trainings, ➢ costs for repair of damaged equipment due to employee's activity.

SYSTEM OF RECOMMENDED INDICATORS OF LOGISTICS – PART 1 Table 21

System of recommended indicators of logistics		
	On-site transportation and material flow	**Distribution**
Indicators of productivity	➢ delivery time ➢ paths covered by a driver, ➢ degree of drivers' efficiency, ➢ average time of repair, ➢ average time of loading and unloading a means of transportation, ➢ value of transported material per an employee.	➢ amount of the dispatched orders per an employee, ➢ productivity of dispatching, ➢ productivity of processing an order, ➢ supplying emergency.
Indicators of quality	➢ meeting the deadlines, ➢ accident rate, ➢ damage rate, ➢ speed of transporting the goods per time.	➢ amount of errors in expedition of goods, ➢ rate of meeting the deadlines, ➢ amount of suspended deliveries, ➢ delivery precision, ➢ rate of claims.
Indicators of economy	➢ costs related to the accident rate of the drivers of transportation means, ➢ costs related to the damage of transported material.	➢ % of costs due to the mistakes of an employee out of the total delivery costs, ➢ costs of the missing amount.

SYSTEM OF RECOMMENDED LOGISTICS INDICATORS – PART 2

Table 22

System of recommended logistics indicators			
	Supply	**Storing and commissioning**	**Production**
Indicators of productivity	➢ volume of outputs per an employee in purchasing, ➢ average response time to the customer requests, ➢ the amount of taken over deliveries by an employee per hour worked, ➢ degree of utilization of an employee, ➢ labour productivity from value added.	➢ Degree of speed of taking over the stocks, ➢ number of storage operations per a warehouse employee, ➢ quantity of material picked up for production per employee, ➢ amount of material picked for distribution per employee, , ➢ volume of the material stored or removed from storage per employee per a time unit.	➢ degree of meeting performance standards, ➢ capacity utilization of production workers, ➢ time of waiting and processing, ➢ number of registered variations in the manufacturing process, ➢ labour productivity per employee, ➢ average number of orders per employee, ➢ downtime caused by employee's performance.
Indicators of quality	➢ average time spent for receipt of goods, ➢ number of errors made in orders per an employee, ➢ observing the time determined for individual tasks, ➢ rate of taking over supplies per an employee.	➢ rate losses incurred in material during handling, ➢ number of errors per employee in picking materials for production, ➢ degree of imperfection of employee's performance, ➢ response time to changes in requirements, ➢ number of errors in the packaging of goods, ➢ speed of material handling, ➢ degree of quality of material storage.	➢ average profitability per employee, ➢ flexibility of response to changes in production, ➢ average time of executing maintenance intervention, ➢ average time from detection of a failure to starting repairs, ➢ number of errors in placing the orders per employee, ➢ production of defective goods per employee.
Indicators of economy	➢ cost due to errors caused by employees, ➢ % of the total cost of acquisition costs due to errors of employees in purchasing, ➢ the cost of increasing work efficiency of employees, ➢ volume of loss of purchasers' performance due to non-complying deliveries.	➢ losses due to errors caused by employee's performance, ➢ cost of missed opportunities, ➢ cost of increasing work efficiency of employees, ➢ average cost of storage space, ➢ costs associated with errors in qualitative and quantitative check.	➢ share the cost of errors in production to total production costs, ➢ cost of staff turnover, ➢ cost of downtime due to employee performance over the given period.

The key condition of meeting the objective in terms of organisation as well as technology and time, is its feasibility. The objective must be accepted by all end-users, i.e. management along with all stakeholders involved in the whole process.

Another condition for achieving a defined objective is its relevance. The objective should be shared by both workers and management. To achieve the required performance and productivity of employees, management should develop favourable working conditions and working environment.

The last condition for successful achievement of the determined objective is its deadline.

The achievement of objectives can be influenced by several factors, such as time, financial needs, human resource, complexity of the organisation, the minimum or optimum achievement of the desired state of the given man-machine-working environment system, demands in terms of processing internal directives and the impact of standards and legislation, the impact of the determined objective on the working environment, demands for the staff's qualifications, multicultural environment and the impact of regional differences.

The influencing factors may be of various degrees of intensity; some factors may have a minimum impact, others may be combined with more issues than listed above. The company should therefore carry out a comprehensive analysis.

3.2.3 Design of rationalisation of ergonomic measures

The second phase in the implementation of the support process of an ergonomic solution is the design phase consisting of two steps: firstly,

designing the rationalisation of ergonomic measures and secondly, testing the proposed measures in real conditions.

The objective of the proposal on rationalisation of ergonomic measures in the man-machine-working environment labour-organisational system is the elimination of deficiencies and minimisation of the impact of negative factors on the employees' musculoskeletal system in terms of ergonomics.

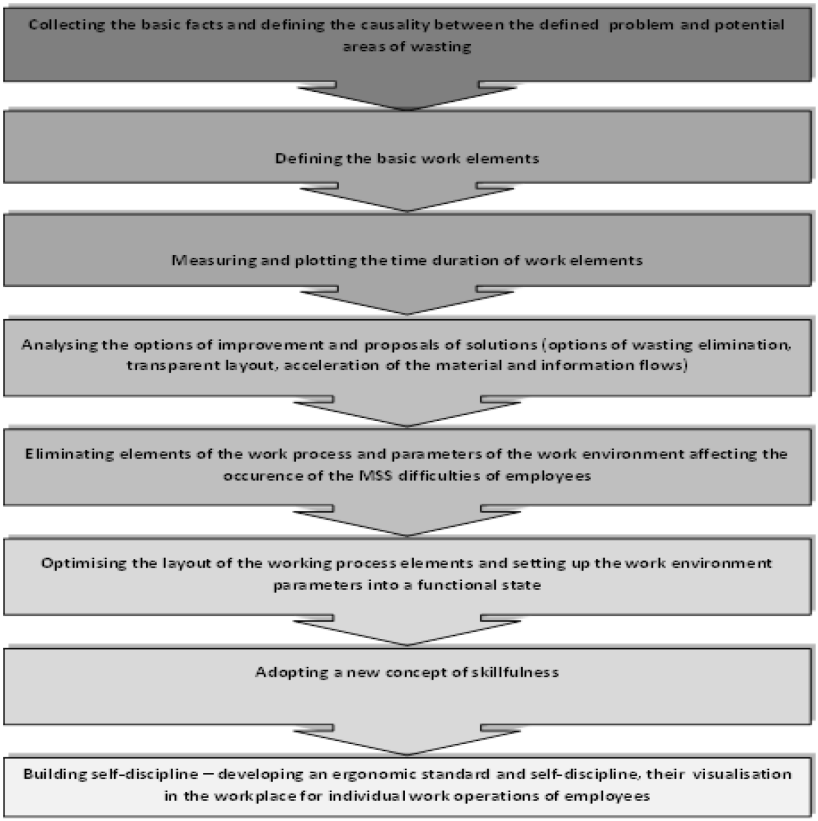


Fig. 24 *Procedure of steps in the design of racionalisation ergonomic measures*

Collecting basic facts

The first stage is understanding the work process. It is necessary to analyse the current work procedure and also to identify the options for improvement. Each process consists of the activities that either add or do not add value. The objective is to minimise the latter, i.e. eliminate wasting from the ergonomics point of view (e.g. minimising the tasks related to searching for necessary information, eliminating excessive walking during the work process, etc.).

Defining basic work elements

The basic work element is the work time e.g. that is needed to obtain parts, loading time of components, time needed for unpacking material, etc. It does not include the time for walking and working without adding value to the final product, such as preparation for work, repair and re-arrangement of workplace. Work elements form a logical sequence of actions leading to successful job completion. They can be described by geographic localisation, function and time. Following is the procedure of defining the essential work elements:

- **defining the initial and final point of the work element**,
- **identifying the walk, low flexion forward and other activities without adding value**, allowing the division of work into core work elements,
- **splitting the basic elements into sub-elements**, if the work within one element is not done with the same components or machines,

- **assuring that elements and sub-elements are approximately of the same duration**, not too short or too long; if an element is short, it can be combined with the following one, but not comprising walking and other activities without adding value.

Measurement and graphical representation of time duration of work elements

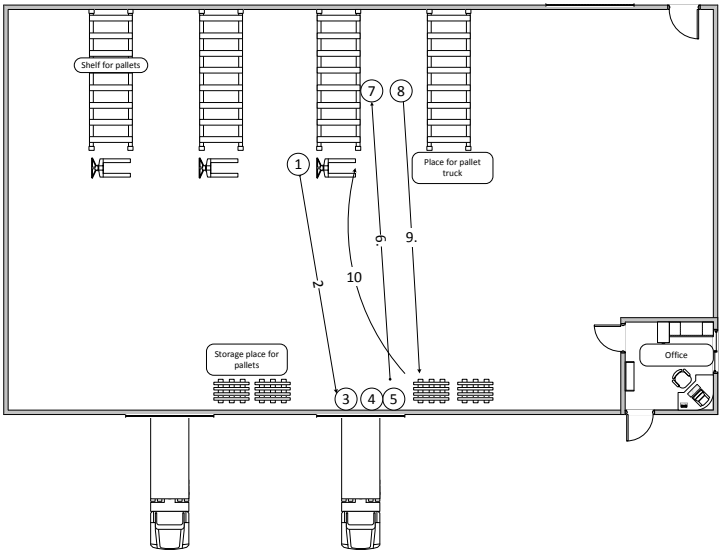
Graphical representation of time duration of the work elements can be helpful for easier and faster detection of wastage in the performance of work activities in terms of ergonomics. It can be done by using two designed record sheets: a time record sheet of employee's elements and a list of work elements.

Firstly, the duration of individual basic work elements is measured. Input data may include the results of video analysis, measurements carried out in the workplace by means of time and motion studies which may help assess the intensity, specification and duration of individual jobs. The following types of time studies can be used: chronometrical shot (continuous, selective, straddle), shot of work course and a movie. Motion studies may involve a method of MTM1, MTM - MTM - UAS or MTM - Logistics. An example of the record is shown in Table 23.

TIME RECORD OF WORK ELEMENTS Table 23

Time record of work elements of employee														
Work operation:		**Elaborated by:**		**Section, operation:**										
Work shift:		**Date:**												
				Length of work element (sec)										
No.	**Work element**	**Starting point**	**Final point**	**1**	**2**	**3**	**5**	**6**	**7**	**8**	**9**	**10**	**Lowest repeated time (sec.)**	**Weighted arithmeti average**
1	Arrival to ramp	Grasping the trolley	Parking the trolley at the vehicle	25	25	26	27	28	25	32	29	30	25	27.14
2	Check of amount	Coming to the pallet	Documents confirmed	20	25	28	30	20	20	24	29	28	20	24.85
3	Check of quality	Comparing the label	Marking compliance (noncompliance in order											
4	Loading pallet	Grasping the troley	Heightening the troley											
5	Transporta-tion to racks	Hightening the troley	Bringing the trolley to the rack											
Total time duration of work elements and weighted arithmetic average														

The most frequent minimum time measured



Records are elaborated according to the following procedure:

- ***record of the work shift, date and name of the person who carries out the measurement, centre or operation, in which the recording takes place,***
- ***record of work elements,***
- ***definition of the initial and final points of the work element,***
- ***measurement of the duration of each work element*** (number of measurements 10),
- ***determination of the prevalent minimum time for each element*** (the lowest and the highest time shall be discarded in order to eliminate the influence of random factors in the implementation of measurement),
- ***times not contributing to value added, such as walking, should also to be measured,***
- ***record of duration of the activities which are random in nature,***
- ***calculation of the weighted average of the measured times,***
- ***Plotting the layout in the table.***

In the next stage, a separate sheet of work elements is elaborated for each basic work element (Table 24). The designed sheet allows documentation of the basic work elements through drafts and their description and definition of the main steps, key points and the reasons why the points were chosen as the key ones.

The worksheet may provide clear working instructions and descriptions, record all the key points associated with each element, map the work time and work history, capture the ergonomics issues relating to each specific

work element, provide information for instructions and trainings in terms of ergonomics and quality of work, facilitate the elaboration of documents for comparing the former state with the present one (time duration of elements, improvement, location of workstations).

WORKSHEET OF WORK ELEMENTS Table 24

Worksheet of work elements					
Common ☒			**Random** ☐		
Work element: Material storage			**Elaborated by:**		**Section, operation:** Input warehouse
Work shift:			**Date:**		
No.	**Main step**	**Key point**	**Reason**	**Symbol**	PHOTO from employee's point of view
1	Lifting material from the pallet	Bend to the palette, crouching	Potential incidence of injury due to excessive bending forward	E	
2	Placing material in a rack	Two-handed work	Potential overloading of muscle groups when using one hand	E	
3	Taking a sheet with bar codes				
4	Sticking on the bar codes	Sticking on the labels on the front side	Access of scanner	Q	PHOTO from observer's point of view
5	Putting the sheet with the rest of the codes aside				
6	Taking a scanner				
7	Scanning the codes	Placing the scanner on the code	Error in the information flows	Q	
8	Putting the scanner aside				
Notes:					

Analysis of design opportunities

The analysis of design opportunities is based on the steps such as collecting basic facts, defining basic work elements, processing tables of worksheets of work elements and time record of employee's elements.

When analysing opportunities, it is necessary to pay attention to the weaknesses ("bottlenecks") and simultaneously define the actions necessary to minimise their impact.

The analysis helps define the opportunities for improvement and identify the counter measures to reduce motion, minimise the consumption of time and force, minimise the positions requiring excessive flexion or an extension of joints, and also identify the necessary investments as well as other expenditures.

When defining the opportunities, the company management will choose the best one from several variations of possible solutions, regarding the financial, technical and organisational possibilities of the company, staff requirements and company objectives.

Eliminating elements of the working process and parameters the of working environment affecting the incidence of disorders of musculoskeletal system of employees

This stage involves the activities related to the elimination of the elements of the working process and parameters of the working environment influencing the formation of disorders and problems of the employees' musculoskeletal system. When implementing this step, it is necessary to establish the criteria for assessing the elements and parameters of the working environment.

This stage will also identify the necessary and unnecessary elements of the work process (pallets, tools, ancillary handling equipment), establishment and limitations of the working environment parameters (excessive airflow, excessive cold) in terms of ergonomics, so that to make room for the elimination of the activities that do not add value.

The analysis can also help eliminate the imperfections identified in the man-machine-working environment system in the following two steps:

- ***determination of the criteria (three categories of importance) for sorting and examining individual elements and parameters of working environmen***t within the man-machine-working environment system, associated with the identification of those elements and parameters of the working environment that influence the incidence of MSS disorders,
- ***subsequent elimination of the elements and parameters of the working environment***, affecting the incidence of the MSS disorders of employees; the members of the group should however realize that some elements may be needed later, and it is therefore appropriate to re-arrange them or store them for future.

Table 25 shows an example of eliminating the disorders.

OPTIONS OF ELIMINATING DISORDERS IN THE WORK-ORGANISATIONAL SYSTEM Table 25

Eliminating disorders		
Man–Machine	**Man–Working environment**	**Man–Work organisation**
Auxiliary handling equipment of poor quality	Unsuitable setting of temperature	Inadequate work pace
Useless tools	Excessive air flow	Over-variability in working conditions
Extra equipment limiting movement	Insufficient lighting	LEXUE
Work above the arm level	Scattered light	Working overtime
Rotation of torso	Excessive vibrations	Insufficient rest

Optimum arrangement of the work process elements and setting the parameters of working environment into the functioning state

Having eliminated the components and parameters of the working environment negatively affecting the musculoskeletal system, it is necessary to arrange all the elements so as to ensure continuity in the implementation of the operations, to protect the elements of the work process from damage and simultaneously to protect the employees performing those operations.

When deciding on the optimum arrangement of the elements, it is necessary to assure the suitability of the chosen location, regarding the distance in terms of accessibility, and to observe the compliance with the decision. This stage is implemented in the following steps:

- ***classification of elements according to the needs and use,***
- ***classification of functional values of the working environment parameters,***
- ***decision on the optimum arrangement of elements and the functional setting of the working environment parameters, regarding the flexibility which may be desirable in the future,***
- ***marking the localisation of elements –*** visualisation (colour coding, shading, written words, silhouettes),
- ***check of efficiency of the selected optimum localisation of the working process elements and the setting up the working environment parameters.***

Adopting a new concept of skilfulness

Stage 7 focuses on developing a new concept of skills, which involves also check and preventive maintenance. It is implemented in the following steps:

- ***define the objective*** - explain to the employees the meaning, purpose and importance of preventive measures,
- ***introduce a set of basic rules*** - demonstrate and illustrate good practice in the implementation of work activities, check and maintenance of machinery and equipment, cleaning the workplace while using economic movements and minimising the load on the musculoskeletal system of employees,
- ***discuss new skills*** - discussions with employees, allowing employees to express their opinion on the implemented measures and actions, accept their comments and proposals for improvements,

- ***visualise procedures of new skills*** - visualisation of demonstrated practices by using appropriate means,
- ***check the adopted concept of new skills*** - checking through direct observation of work activities of employees, associated with corrections and practical demonstrations.

The stage is also intended to systematically and routinely implement the above-mentioned steps, thus building the employee's discipline. The discipline of employees in turn means that they comprehend and are able to practically apply the established rules, while eliminating their own bad habits and seeking the opportunities for sustainable improvement within the man-machine-working environment system. Besides acting within the established rules, discipline supposes also analysing the problem, and allowing the employees themselves to identify its causes to be eliminated.

Building self-discipline

The final stage in the implementation of corrective actions is building self-discipline along with the application of ergonomic standards. The stage is aimed at developing the standards the employees will use to measure the previous seven stages. The standard will help employees to identify abnormalities and deviations from the desired state of the man-machine-working environment system, and enable them to adequately and timely respond to the given situation. To achieve continuity in the implementation of the above-mentioned stages, it is necessary to decide how often they should be implemented and who will be involved.

3.2.4 Testing the designed rationalisation measures in real conditions

In testing the proposed technical and organisational measures, it is recommended to use the principle of visualisation design. This will provide a source of information available to all employees, so that they can view the presented proposals and draw conclusions themselves.

The procedure of visualisation of proposed measures is accompanied by the rapid and efficient communication and their subsequent implementation into practice:

- ***determining the goal of visualisation*** (visualisation of the changes in the workplace layout and in placing the pallets and ancillary handling equipment after their use),
- ***determining the content of visualisation*** (graphical representation of unsuitable working positions of employees in the process of handling materials manually when preparing them for production,
- ***specifying the means of visualisation*** (horizontal signs indicating the movement of auxiliary transport facilities for the transportation of materials for production),
- ***defining accountability for the implementation of visualisation.***

Goal of visualisation.

The successful implementation of the proposed rationalisation of ergonomic measures and utilisation of visualisation principles aimed at minimising the impact of risk factors on the musculoskeletal system of employees require the following actions:

- ***visualising the parameters and factors affecting the occurrence of potential imperfections in terms of ergonomics and disorders of musculoskeletal system of employees,***
- ***visualising the parameters and factors affecting the occurrence of potential imperfections in terms of effectiveness of performed processes,***
- ***utilising visualisation for the re-arrangement of elements, and adjustment of the man–machine–working environment system,***
- ***identifying potential wasting of workforce, space, movement and time,***
- ***identifying troublesome ergonomic areas,***
- ***increasing personnel motivation in performing the work tasks,***
- ***increasing familiarity with the implementation of the support process of ergonomic solution,***
- ***continuously assessing the impact of implemented measures.***

Content of visualisation

The goal of visualisation is to raise the interest of employees and make them familiar with the information related to the proposed and implemented ergonomic measures. Simultaneously, it should challenge the employees to accept the proposed ergonomic measures designed to adapt the work conditions and working environment to the benefit of staff.

Following is the structure of the basic content of visualisation of the ergonomic measures implementation:

- ***effectiveness of the performed work*** (comparison of the monitored indicators for individual time periods),

- ***absence*** (visualisation of the length of absence in relation to the work performed),
- ***working positions + suitable working positions*** (visualisation of suitable and unsuitable working positions in performing work activities),
- ***working movements + suitable working movements*** (visualisation of suitable and unsuitable working movements in performing work activities),
- ***incidence of the MSS disorders,***
- ***layout of workplace.***

Means of visualisation

Fast and effective visualisation of the designed ergonomic measures requires suitable means, e.g. noticeboards, horizontal marking of the work area e.g. racks for pallets and other active or passive handling equipment, marking of the workspace of an employee, marking of the dangerous and leisure zones, marking of the walking zones and transportation corridors. Other possible use is the marking of the space for tools and auxiliary equipment, the use of colourful ribbons, labels and markers on the machinery and equipment.

Responsibility for the implementation of visualisation

The head of the department bears responsibility for the implementation of visualisation. The responsible person should arrange visualisation of information on the implemented ergonomic measures, provide funds and assure the achievement of the visualisation goals.

3.2.5 Check and evaluation of the effect of the designed rationalisation measures

The aim of the feedback cycle is to compare the determined objectives, original intentions and ideas with the results achieved. This can reveal potential discrepancies as well as suggest the means of their elimination. The process of checking should be carried out in compliance with the principles such as: self-discipline, feedback, comprehensiveness, continuity, feasibility (economic and pragmatic), economy and accuracy in particular. The following scheme in Figure 25 outlines three basic steps of the control process.

In the first step, it is important to prepare the timing (schedule) of the check for achieving the goals that had been clearly and precisely defined. After determining the date of check, a suitable process and methodology should be determined regarding the aim of check.

A cohort study is one of the tools that can be used to verify the outcomes. The study compares the impact of the measures of the proposed check and evaluation of the impact of the proposed and implemented measures. It is carried out on two basic levels. Level 1 is the continuous check and evaluation. Level 2 is the final check and assessment of the effects of the proposed measures in terms of ergonomic indicators and work efficiency regarding the determined logistics indicators.

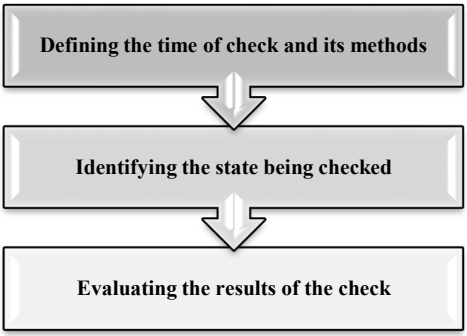


Fig. 25 *Basic procedure of checking the efficiency of the designed ergonomic measures*

Recommended intervals of the continual check implementation are shown in Table 26; a company can however choose the intervals depending on the particular situation and its own needs.

PROPOSAL OF A BASIC SYSTEM OF SETTING UP THE CONTINUOUS CHECK Table 26

Degree of difficulty	Deadline for achieving the objective	Intervals of continuous assessment
Light	3 months	3 weeks
Semi-difficult	9 months	1.5 month
Difficult	12 months	1 month

Final or overall assessment is carried out according to the terms set out in the target. Final inspection should be carried out by repeating the procedure of the analysis phase in order to compare the initial state with the state of the selected period.

There are three levels of achievement of the objective in the field of business logistics, and two levels in the field of ergonomics, as shown in Table 27.

LEVELS OF ACHIEVEMENT OF AN OBJECTIVE Table 27

	Ergonomics	**Business logistics**
Level of the objective achievement	Achieved objective	Achieved objective
	–	Partially achieved objective
	Unachieved objective	Unachieved objective

In terms of ergonomics, there are two ways of assessing whether the objective was achieved or not. Achieved objective means that the introduced measures yielded a positive effect without any impact on the health of staff. Unachieved objective indicates that the proposed measures missed the desired target and exhibit either zero or even negative effect. In terms of business logistics, each company can determine the level of the objective achievement regarding the needs and desired values of the monitored parameters: achieved, partially achieved and unachieved objective.

Following the check of goals achievement, the next phase of the support process of ergonomics solution in the field of business logistics is the step, *the Introduction of the ergonomic standard for the proposed rationalisation measures*, or, in the case of partial achievement or non-achievement, the step, *Revision of the previous cycl*e.

3.2.6 Development of ergonomic standards for the designed rationalisation measures

To achieve the objectives in terms of ergonomics as well as business logistics, it is appropriate to develop a standard for the designed ergonomic rationalisation measures in order to ensure the improvement of the initial state, i.e. processing and implementation of concepts, policies, procedures and ergonomic designs regarding the elimination of the MSS disorders of employees in order to achieve and sustain compatibility and conformity, which are important for optimising the use of resources.

The designed standard represents a milestone that provides room for further continual improvement in terms of ergonomics. The development of ergonomic standards for the proposed rationalisation measures is implemented in a sequence of steps, as illustrated in Figure 26.

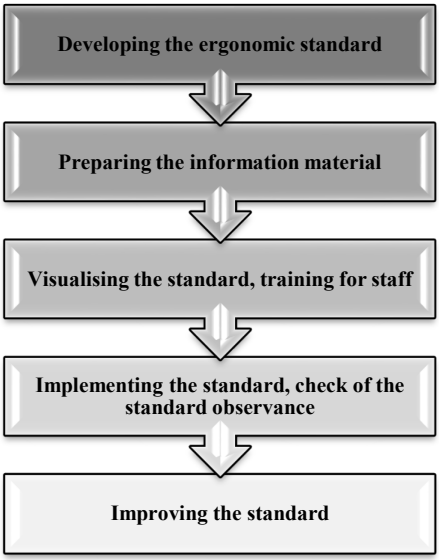


Fig.26 *Procedure of developing an ergonomic standard*

Development of the ergonomic standard

The ergonomic standard is developed as a logical sequence of the following steps. In Step 1, it is necessary to appoint the person responsible for developing the standard, specify the deadline, as well as appoint those who will approve the standard. The responsible person shall thereupon submit the standard to reviewers for review and approval. Step 2 determines the application area of the standard. Step 3 defines the purpose and aim, i.e. specification of the intended outcome and the future anticipated positive value of the implemented ergonomic measure. Step 4 defines the concepts and expressions related to the elaborated ergonomic standard. The final step is the implementation of the developed standard.

Preparation of promotion materials

Promotion material is designed to support successful implementation of the ergonomic standard and its acceptance by employees. It should help employees to understand and adopt the standard, and inform them about the intended improvement of working conditions and working environment in order to increase their work efficiency and minimise the impact of work and working process elements on the incidence of the MSS disorders.

Visualisation of standard and staff training

To assure a wide adoption and minimise the potential risk of employees' negative attitudes to the implemented changes, the developed standard should be generally available to all employees. Various visualisation means can be used, e.g. an electronic screen periodically displaying the standard accompanied with a commentary on its significance. Another way of improving the staff's awareness is a leaflet introducing the established standard and containing the basic information about it, accompanied by the illustrations providing better visualisation for all of the employees concerned. This phase is followed by the training on the introduced ergonomic measures.

Implementation and check of the standard observance

After the above-mentioned visualisation and training phases, the standard is implemented into the company practice.

The established standard becomes mandatory for every employee, while the responsible person assures that all affected employees work in compliance with the established standard. The check focuses rather on the work activities performed by the staff, but not on the employees themselves.

The responsible person walks around the workplace at regular intervals and monitors the performance of individual employees. In the case of non-compliances with the accepted standard, s/he notifies the employee and then demonstrates a good practice in terms of ergonomic standards, in order to minimise the risk factors affecting the emergence of diseases and related health damage negatively influencing the labour effectiveness of employees.

Improvement of standard

The standards facilitating the improvement of the labour efficiency and competitiveness of the company must also be improved. The proposed changes are not permanent, but temporary, and therefore it is necessary to improve continuously the working conditions and procedures established by the ergonomic standards. The support process of an ergonomic solution implies an approximate approach to the achievement of the final objective. The designed standard therefore supposes continuous implementation of the ergonomic solution depending on the level of achievement of the objective.

3.2.7 Revision of the previous cycle

Reviewers may use their experience to identify the causes of insufficient achievement of the objectives, and focus their activities on eliminating the deficiencies. The entire support process of the ergonomic solution can thus be repeated until the desired results are achieved, both in terms of workers' health and the required efficiency of their work.

Feedback can be used to minimise the time consumption related to the recycling of the entire support process of the ergonomic solution and identify the causes of insufficient achievement of the objective. Critical thinking

based on the synthesis of a number of factors is an integral part of the activities of the ergonomic team as it represents the way of transferring the results acquired to feedback.

The following questions may be raised in feedback:

- ***what if?*** – …particular steps were implemented in a different way, if they were not implemented at all,
- ***how could?*** – … a particular step lead to problems,
- ***what does it mean for?*** – … a successful implementation of further steps,
- ***and why?*** – … is particular information/step necessary, what does it bring.

If the desired level of solution is achieved, i.e. the initial state has been improved; it then becomes the subject of further improvement. Management determines new goals that subsequently provide space for the support process of the ergonomic solution, for attracting an efficient workforce and developing suitable working conditions necessary to minimise the impact of risk factors and assure sustainable competitiveness of the company.

3.3 Personnel, organisational, technical and financial issues related to the design

Successful application of the support process of an ergonomic solution requires the necessary personnel, organisational, technical and financial provision.

3.3.1 Personnel issues

A prerequisite for the real and successful application of ergonomics as the basis for the development of appropriate working conditions is a specific work position of an employee who would be a part of the corporate organisational structures. When designing the position, it is necessary to explain the job description (specification of the position, description of purpose and tasks of the job, relations of superiority and subordination, definition of the powers and responsibilities), as well as the job specification (requirements, both necessary and useful, for prospective employee, physical and mental qualities, education and qualifications, experience, training and skills, personality traits, specific requirements: age, sight, hearing, touch, etc.).

Job description

The work position of a manager-expert in the field of ergonomics requires higher qualifications and the abilities to plan, assure and coordinate the tasks under the laws and regulations, assure methodological, management and control activities, examine and handle complaints, provide consultancy and organisational ergonomic support in developing suitable working conditions for effective and safe work of employees.

Following is the job description of a manager-expert in the field of ergonomics:

- ***elaborating the proposals of complex ergonomic concept*** for effective assurance of rational performance of work activities, health protection of employees, property protection, along with the determination of the requirements for tangible and intangible resources,
- ***elaborating and commenting on the proposals*** of work procedures, technical and technological changes,
- ***planning, preparation, implementation and checking of the company ergonomics projects***,
- ***analysing the ergonomic situation*** and assessing the health risks in terms of ergonomics,
- ***preparing and keeping related ergonomic documentation***,
- ***elaborating internal regulations and standards*** in the field of ergonomics, occupational health and safety,
- ***monitoring and assessing the effectiveness of the implemented measures*** ensuring the ergonomic working conditions in terms of employees' health and economic efficiency of the company,
- ***monitoring the compliance with legislative and corporate regulations*** in the performance of employees in terms of ergonomics, work hygiene, health and safety,
- ***compiling evaluation reports*** for the senior management, regarding various areas of activities.

Job specification

A job specification expresses the total set of demands for skills, abilities, competencies and personality traits necessary to perform the job. A job

specification also comprises the requirements for professional skills and knowledge, transversal skills, general competences and personality capabilities of prospective employees. The professional skills should be based on the activities and duties of the employee.

Following are the required professional skills:

- ***preparation and implementation of partial ergonomic projects***,
- ***proposal of concepts, planning, preparation, implementation and checking*** of the system of ergonomic projects in the company,
- ***development and implementation of an ergonomic solutions regime*** for the health and property protection of employees,
- ***preparation and storage of ergonomic documentation*** in case of service and emergency situations (accidents, injuries, health damages),
- ***providing consultancy, lecturing*** and support in the field of ergonomy,
- ***implementation of visual inspections*** aimed at monitoring the impact of ergonomic risks,
- ***providing primary activities***, such as the development of preventive measures aimed at the elimination of dangerous impact risk factors in terms of ergonomy.

The following Tables 28 and 29 provide examples of requirements (general competences and personality traits) for the position of a manager - specialist in the field of ergonomics.

GENERAL COMPETENCES Table 28

General competences	
Inevitable	**Desirable**
➢ language skills (reading and translating simple texts)	➢ legal competencies (orientation in the field of ergonomy and occupational safety),
➢ working in a team (team support, accepting and providing feedback, defending one's own aims and proposals in compliance with the team's aims)	➢ language skills (common communication, reading and writing texts)
➢ motivating people (motivation via clear objectives)	➢ working in a team (sharing new information and knowledge, understanding the team dynamics),
➢ creative thinking (improving the existing procedures and solutions, searching for new ways of increasing the quality of working environment and productivity)	➢ personal development (identification of chances and sources of personal development, assessment of one's own potential),
➢ negotiating skills (reasoning in discussion regarding its aim)	➢ motivating people (by one's own example)
➢ dealing with people (effective, tactful and topical)	➢ negotiating (choice of appropriate style and register depending on the situation, using the right reason)
➢ organising and planning the work (setting realistic objectives, planning capacities and schedules),	➢ leading people (coaching, visionary, invention, developing imagination
➢ computer skills (mastering Office Package and standard user operations with the operation system)	➢ dealing with people (chairing meetings and workshops, challenging communication)
➢ technical skills (understanding principles and functions of engineering systems and equipment),	➢ writing and written communication (effective reasoning in writing)
➢ problem solving and analysing (assessing the factors of the given solution within the given context)	
➢ processing information (quick orientation in the amount of information and assessment of reliability of information sources)	

GENERAL COMPETENCES Table 29

Personal dispositions	Demands
Memory	
Short-term	3
Long-term	4
Attention	
Concentration	4
Division	3
Vigilance	3
Imagination	
Spatial and constructional	3
Processes and events	3
Thinking	
Theoretical	3
Autonomous	4
Creative	4
Other mental demands	
Well-developed written and oral communication	4
Flexibility	3
Autonomy and self-control	3
Accuracy, precision	3
Resistance to mental stress	3
Dealing with people	
Pleasant behaviour and appearance	4
Self-confident and dexterous acting	3
Sociability	3

Legend: (Supposed): **1** negligible demands, **2** low demands, **3** moderate demands, **4** high demands, **5** extraordinary demands

A comprehensive description of the job should be prepared by the personnel department in cooperation with other managers on all levels of management, in order to reflect the real situation, future needs of the company and practical applicability of the resulting job description. Individual components of the job are just recommended, as the job description is not definitive and will be constantly revised in response to the sustainable changes the company will be exposed to. Each company may

therefore prepare a more detailed specification adapted to the current conditions and needs.

3.3.2 Organisational issues

To provide the implementation and application of ergonomic activities and to create the ergonomic working conditions and working environment, it is appropriate to establish an ergonomic working group of employees who would be actively involved in the process of developing a team ergonomic solution. Activities of the ergonomic working group would focus on the assessment of the working conditions and working environment, the analysis of the current situation and the implementation of ergonomic projects with the aim to minimise the impact of risk factors. These activities are important for motivating the employees exposed to risks factors in terms of ergonomics.

An ergonomic working group can be established in two ways. It may be either formed within the existing structures of employees, e.g. quality circles, by enhancing their activities and focusing on specific problems of the employees' musculoskeletal system; or a new working group may be formed of employees, managers, experts in the field of ergonomics, consultants and representatives of management.

Following are the recommendations for the ergonomic working groups:

- ***activities of ergonomic working groups should be supported by the company top management***, in order to assure their successful performance and internal communication within the group,

- ***participation in the activities of ergonomic working groups should be voluntary***, i.e. no one can be forced to become a member, though directive approach of the company management may be expected in the first phase of building the group,
- ***in the first phase of building the group, the leader of the ergonomic working group should be a manager – expert in the field of ergonomics,***
- ***members of ergonomic working groups should attend regular trainings, seminars and lectures,***
- ***members of the ergonomic working groups should meet at regular intervals***, depending on the seriousness of the situation, once every half a year at a minimum,
- ***activities of the ergonomic working groups should be focused on the implementation of specific ergonomic tasks,***
- ***an accomplished project (specific task in a workplace) does not terminate the work of the ergonomic working group***; in compliance with continuous improvement, it is necessary to identify new chances for improvement,
- ***members of ergonomic working groups should adopt the following philosophy***: "problems are just chances for improvement",
- ***each proposal of the members of an ergonomic working group means a step forward.***

Graphical representation of an ergonomic working group activity described below is illustrated in Figure 27**.**

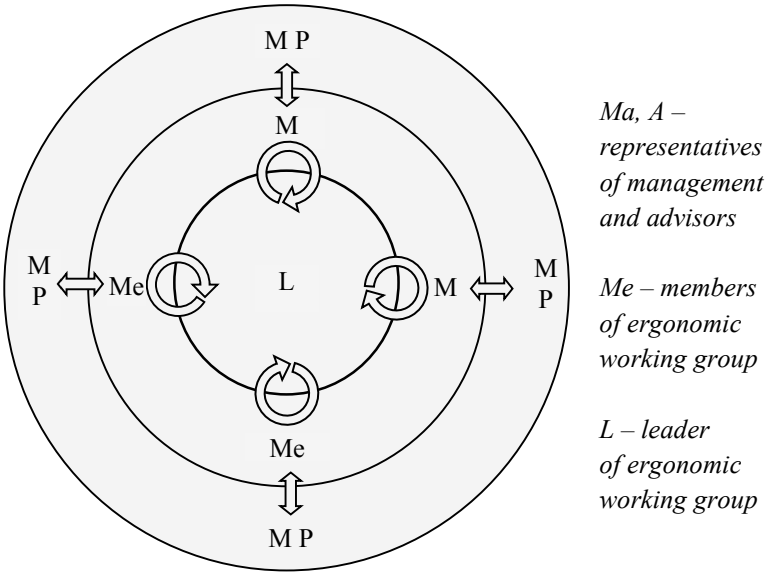


Fig. 27 *Cycle of an ergonomic working group within a company*

The group leader performs the roles of a planner, coordinator, mediator and controller.

As a planner, s/he elaborates the plan and implementation of the ergonomic solutions, plans meetings and sets deadlines for the individual phases of the support process of obtaining an ergonomic solution and writes reports of regular meetings for the group members, management representatives and consultants.

As a coordinator, s/he co-operates with management and consultants, makes them familiar with the identified needs of the group members, assists the members of the ergonomic working group to deal with the ergonomic issues related to their activities, and co-operates with the organisations providing trainings for the members of ergonomic working groups.

As a mediator, s/he prevents conflicts that might occur between the members of ergonomic working group and the management or within the group itself in the implementation phase of the support process of obtaining an ergonomic solution.

The leader of the ergonomic working group identifies the conflict before it grows to a cause. As a mediator, s/he is impartial, creates a climate of comfort and understanding, communicates with the interested parties, conducts constructive negotiations, identifies problems and clarifies misunderstandings.

A controller, s/he carries out the activities related to monitoring the deadlines observance, checks the correctness of the submitted results together with advisors from the field of business logistics, ergonomics and, if necessary, occupational safety, checks the commitments of the group members and management, and monitors the achievement of the objectives, both partial and final.

Members who voluntarily enter the ergonomic working group are actively involved in the support process of obtaining an ergonomic solution under the terms established by the group leader.

Management should actively support and check the activities of ergonomic working groups. A representative of management should be a member of an ergonomic working group, supporting the activities of its members.

Management should create conditions for the implementation of the decisions of the group members by delegating the powers to the manager–expert in the field of ergonomics, providing the necessary financial resources for the implementation of the proposals of the ergonomic working group

members, motivating the members by various forms of remuneration (appraisals in public, financial benefits possibly for each implemented proposal, depending on the number and quality of the proposed solutions), and providing souvenirs and vouchers for the purchase of books, vitamins, etc.

The management representatives should also regularly check the activities of the ergonomic working group members in the meetings of members, check the achieved results as well as the level of objectives achieved, and provide feedback necessary to determine the effectiveness of the support process of ergonomic solution.

The consultants supervising the activities of the members of the ergonomic working group should be elected from the field of ergonomics, occupational safety, health services, business logistics, or technology. They may be either company internal employees, or external experts from various consulting firms or institutions of the higher education sector.

The consultants discuss the proposals of the individual members of the working ergonomic group, participate in the implementation and monitor the regularity of solutions on the technical level.

The ergonomic working groups reinforce the role of employees in solving the tasks related to the minimisation of risks of accidents, illnesses and injuries which are due to e.g. long-term unilateral exposure. Individual group members can utilise their skills and experience gained directly in the processes carried out within business logistics.

Anticipated benefits and positive effects resulting from the activities and performance of ergonomic working groups are as follows:

- ***minimisation of the impact of risk factors*** in terms of ergonomics, such as extreme or unnatural positions of joints, static stress, force, frequency or repetitive work, etc.,
- ***improvement of employees' health state*** (improved indicators of incidence, prevalence, fluctuation, sickness rate),
- ***reduction of monotonous and repetitive work*** contributing to the dejection of intellectual aspects of employees' personalities and their manual skills (minimising the impact of long-term, excessive and unilateral exposure by a suitable choice of rotation and regime of work and rest),
- ***reduction of heavy physical work*** (choice of active logistic elements, such as handling, storing and transportation devices),
- ***improvement of work safety and comfort*** in individual workplaces (warehouses, production halls, offices) via thorough signing, labelling and marking, and setting up suitable microclimatic conditions,
- ***saved time*** by reducing redundant movements with no added value e.g. in handling heavy loads,
- ***increased quality of the manufactured products*** by creating suitable conditions of working environment and organisational measures affecting the employees' concentration,
- ***improvement of relationships and communication between the management and employees,***
- ***improvement of relationships and communication of employees,***
- ***employees will be willing and able to solve problems themselves,***
- ***improvement of work morale,***
- ***higher job satisfaction and feeling of ownership.***

3.3.3 Technical and financial issues

Implementation of the support process of obtaining an ergonomic solution designed to apply ergonomics in business logistics and minimise the effects of risk factors of the incidence of disorders and damage of musculoskeletal system of employees requires certain technical and financial background, particularly:

- ***premises and rooms,***
- ***computational technology,***
- ***projectors,***
- ***screens,***
- ***noticeboards,***
- ***wages,***
- ***trainings.***

Organisational or technical measures cannot be exactly quantified, since their level depends on the specific conditions in individual companies.

CONCLUSION

"I am interested in my future because that is where
I am going to spend the rest of my life."
Charlie Chaplin

Companies are currently confronted with the turbulent market environment, variable customer requirements and technological advances challenging further innovations in various functional subsystems of logistics, i.e. supply, storage, handling, manufacture, packaging and distribution. The emphasis is on productivity and maintaining its status quo or increasing it, thus enabling the enterprises to survive on the current markets.

In terms of production, it is not enough just to shorten lead production times of production, increase the rate of production, increase the work overtime; it is also necessary to monitor the impact of the required output on workers. To ensure employees' productivity, the company needs healthy, rested, satisfied and well-trained working staff producing high quality output. This can be achieved via ergonomics as a scientific discipline aimed at assuring good health of employees and their physical, mental and social well-being.

Ergonomics helps create the conditions and limits of exposing a man to the workload, when he is not able to perform in the long-term horizon without harm to his health. It is therefore necessary to focus on the integration of ergonomics and its principles into various areas of logistics, to secure economic objectives of the company on the one hand, and good health of employees representing the pillar of the sound performance of the enterprise as a whole, on the other hand,

We believe that implementation of the proposed procedure and the utilisation of the related tools will help create the work environment in which employees can produce a stable output with minimum impact of risk factors leading to occurrence of diseases of musculoskeletal system due to long-term excessive unilateral exposure and psychological discomfort.

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