

PROVIDING RECOMMENDATIONS BASED ON THE STUDY OF WORLD EXPERIENCES ON THE ERGONOMIC DESIGN OF MODERN PRODUCTS

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Abstract: This scientific article studies world experience in ergonomic optimization of modern production systems and analyzes their effective aspects. It is shown that ergonomic design is of great importance in ensuring human health, labor productivity and safety. During the study, industrial practices in Germany, the USA, Japan, Sweden and other advanced countries were studied and recommendations adapted to the conditions of Uzbekistan were developed. The integration of ergonomics with technological progress, including advanced approaches developed on the basis of digital engines, ergonomic monitoring using AI, simulation and virtual prototyping methods, were analyzed with special attention.

Keywords: ergonomic design, industrial production, world experience, occupational safety, digital ergonomics, production efficiency, anthropometry, safety culture.

Introduction. The approach of ergonomics to such urgent issues as the organization of labor activity in modern industrial systems, the preservation of human health and increasing production efficiency is becoming increasingly important. In particular, the design of workplaces, equipment and production processes on production lines, taking into account the physiological and psychological capabilities of the human body, is one of the modern requirements. Ergonomics has become not only a technical approach, but also an integral part of the socio-economic, health and human resource management strategy [1].

At the current stage of industrial development around the world, ergonomic design plays an important role in processes involving human participation. The increasing complexity of industrial technologies, the increase in the number of automated systems, create the need to optimize the interaction between workers and machines. Therefore, ergonomic design is now considered a strategically important factor for production efficiency and safety [2].

For example, in Japan and Sweden, companies that implemented ergonomic approaches have seen a 20–25% increase in productivity and a 30–40% reduction in occupational diseases and injuries [3], [4], clearly demonstrating the practical benefits of ergonomic design.

Leading countries in the field of ergonomics - such as Germany, the USA, Sweden, and Japan - have introduced modern scientific and technical approaches into their industrial systems. These include individualization of the workplace based on anthropometric data, the use of IoT devices for workload monitoring, consideration of cognitive ergonomics, and the development of a safety culture [5].

For example, research conducted at NASA in the US on human-machine interface has shown the high efficiency of ergonomic integration into manufacturing technologies [6]. In Germany, a great emphasis is placed on human-centered production models within the framework of the Industry 4.0 concept [7].

The incomplete implementation of ergonomic standards in Uzbek industrial enterprises leads to many negative consequences. Including:

- Low labor productivity,
- Occupational diseases and orthopedic problems (musculoskeletal system),
- Decreased employee motivation,
- Increased days of incapacity for work.

To improve the current situation, it is necessary to adapt ergonomic design approaches to national production systems, conduct a thorough analysis of international experience, and strengthen them with legal standards.

The main goal of this study is to study ergonomic design experiences in advanced manufacturing enterprises around the world, analyze their successful aspects, and develop recommendations for industrial sectors in Uzbekistan.

Methods. Research design. This study aims to analyze ergonomic design practices in modern manufacturing enterprises and develop practical recommendations based on world experience. The study was conducted using descriptive and analytical methods. The reason for choosing this method is to provide an in-depth study of the current situation, identify practical problems, and provide the opportunity to compare with international practices.

Data sources. The following types of information sources were used for the study:

- ✓ Scientific articles, dissertations, international ergonomics standards (ISO 6385, ISO 9241, etc.);
- ✓ Practical reports on ergonomic solutions in manufacturing plants in the USA, Germany, Japan, and Scandinavian countries;
- ✓ Recommendations and statistics published by international organizations on labor protection (ILO, OSHA, EU-OSHA);
- ✓ Tools, software, and methodologies used in ergonomic analysis (REBA, RULA, NIOSH Lifting Equation, etc.).

Data collection methods. The following data collection methods were used in the study:

✓ **Systematic analysis of literary sources:** Articles on ergonomic design published between 2015 and 2024 from scientific databases such as Scopus, Web of Science, and Google Scholar were analyzed.

✓ **Case studies:** Practical approaches to the ergonomic organization of modern production lines were studied at Tesla Gigafactory in the USA, Bosch in Germany, and Toyota in Japan.

✓ **Expert interviews:** Online interviews were conducted with occupational health and ergonomics experts ($n = 6$). The interviews discussed key challenges and successful strategies in ergonomic design.

Analysis methods. The collected data was analyzed using the following approaches:

✓ **Contextual analysis:** Ergonomic approaches in each country were studied depending on the production culture, labor legislation, and level of technological development.

✓ **SWOT analysis:** The strengths and weaknesses, opportunities and threats of ergonomic systems in modern production were identified.

✓ **Comparative analysis:** Ergonomic design methodologies in different countries were compared, and universal and adapted strategies were distinguished.

Research limitations. This study was based mainly on open source (online) data, and did not have full access to the internal ergonomic processes and technical details of some enterprises. Also, the number of expert interviews was limited, which somewhat reduces the possibility of generalization. However, a sufficient empirical and theoretical basis was formed to draw reasonable conclusions based on the available data.

Results. This study analyzed international approaches to ergonomic design in modern production and, based on them, identified factors that have a positive impact on production efficiency and employee health. The main results are detailed below.

Main ergonomic approaches used in world experience. The following ergonomic approaches were found to be widely used in more than 20 leading enterprises and scientific sources analyzed:

Country	Type of practice	Description
USA (Tesla, Boeing)	Workplace modularization and AI monitoring	Monitoring worker actions through artificial intelligence, automatically detecting errors.
Germany (Bosch)	Anthropometric adaptation	Each workstation is adjusted to the body structure of the worker.
Japan (Toyota)	Kaizen and the 5S method	Continuous improvement and streamlined workplace organization.
Sweden (Volvo)	Adaptation to lighting, temperature, and noise	Optimization of ergonomic microclimate indicators.

These practices have been reported to increase production productivity by an average of 15–30%, and reduce worker health problems by 20–40%.

Types and identification of ergonomic hazards. Based on expert interviews and theoretical analysis, the following ergonomic hazards were identified as the most common factors:

- **Long-term work in a static state** (for example, standing in one place or working in a crouched position);
- **Lifting heavy load** sand moving in the wrong position;
- **Repetitive movements of body parts** (especially in the wrists, elbows and shoulders);
- **Visual stress** (unclear vision in poorly lit areas);
- **Psychological pressure** (processes requiring speed).

These risks were identified through the REBA and RULA assessment methodology, with assessment scores of 7 or higher in most production locations, indicating that immediate action is required.

Positive indicators achieved as a result of ergonomic design. The following table summarizes the main results observed in enterprises where ergonomic measures have been implemented:

Indicator	Ergonomic measures	After ergonomic measures
Complaints of lower back pain	42%	18%
Production defects	12%	6%
Employee job satisfaction level	60%	85%
Referrals to a doctor with professional complaints	35%	14%

Customization options. The results of the analysis show that the above best practices can be adapted to the conditions of Uzbekistan in the following cases:

- Ensuring anthropometric compliance through modularization of workplaces and adjustable desks/equipment;
- Developing inexpensive monitoring systems that track movements using simple sensors;
- Introducing simple organizational methods such as "5S" and "Kaizen";
- Incorporating ergonomic design modules into national occupational safety training programs.

Discussion. This study provides an in-depth analysis of ergonomic design practices in leading manufacturing companies around the world, and scientifically demonstrates the positive impact of these approaches on productivity, worker health,

and quality of work. The analysis based on the research results and their relevance in the context of Uzbekistan are discussed below.

Comparative analysis of world experience and the Uzbek production system.

Ergonomic design has become an integral part of improving labor efficiency in the United States, Germany, Japan, and Scandinavian countries. In these countries, production processes are coordinated through modern technologies, artificial intelligence-based monitoring systems, modular workstations based on anthropometric measurements, and continuous ergonomic monitoring.

On the contrary, in many manufacturing enterprises in Uzbekistan, workplaces are still organized in a classic, standardized and uniform manner, without taking into account individual needs, human body structure and physiological capabilities. This situation leads to excessive strain during work, musculoskeletal disorders and fatigue syndrome.

Therefore, the introduction of ergonomic design into the national production system is both relevant and economically feasible.

Economic and social benefits of ergonomic design. Based on the research results, the following were determined:

- Ergonomically designed workplaces can help increase worker productivity by 15–30%;
- The use of mechanized systems when working with large loads not only speeds up the process, but also reduces the number of injuries by up to 40%;
- With reduced psychological and physical stress, employees' job satisfaction increases, leading to increased commitment and reduced turnover.

In countries where ergonomics are accepted as part of occupational health and safety (e.g. Scandinavia), occupational health indicators are maintained at high levels. On this basis, long-term economic benefits can be obtained by systematically implementing ergonomic solutions in the Uzbek production system.

The importance of advanced technology-based approaches. The study notes that the ability to monitor worker movements, detect uncomfortable situations, and automatically alert them using artificial intelligence, smart sensors, and IoT (Internet of Things) technologies plays a key role in preventing ergonomic problems. These technologies enable real-time safety management in modern manufacturing.

It is recommended that simple and affordable technological solutions – such as sensor-based status analysis systems and devices that automatically adjust workplace lighting – be gradually introduced in Uzbek enterprises. This phased approach will be technologically and financially feasible.

The need for recommendations adapted to local conditions. World practice has shown that the successful implementation of ergonomic solutions only yields positive results if they are adapted to the local context - social, cultural and economic

conditions. In the conditions of Uzbekistan, the following factors are important:

- Regular training and preparation of visual materials to improve the ergonomic literacy of workers;
- Integrate ergonomic requirements into national labor legislation;
- Development of a simplified ergonomic assessment methodology for small and medium-sized enterprises;
- Introducing ergonomic design science in technical schools and universities.

Research limitations and future directions. This study was conducted based on open sources and a limited number of expert interviews. Therefore, the results may not be fully generalizable to broader industries. Future research would be to conduct an ergonomic assessment in real manufacturing facilities in Uzbekistan and develop a national model.

Conclusion. The results of the study showed that ergonomic design in modern production is an important factor not only in maintaining the health of workers, but also in increasing production efficiency. Advanced approaches used in world experience, in particular, anthropometric adjustment, AI-based monitoring and the application of Kaizen principles, have yielded positive results. In the conditions of Uzbekistan, it is possible to improve labor protection and increase enterprise efficiency by adapting these experiences to the specifics of local production. On this basis, it is recommended to gradually integrate ergonomic approaches into the national labor system.

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