Journal scientific and applied research, vol. 28, 2025
International Journal

ISSN 1314-6289 (Print)
ISSN 2815-4622 (Online)

Original Contribution

RESEARCH ON THE APPLICATION OF ERGONOMICS IN ACTIVITIES RELATED TO ENGINEERING LOGISTICS

Yordanka Yankova-Yordanova[1], Yordan I. Doychinov[2], Soniya K. Vachinska-Aleksandrova[3], Nikolay H. Yordanov[4]

[1]DEPARTMENT OF ENGINEERING LOGISTICS, FACULTY OF TECHNICAL SCIENCES, KONSTANTIN PRESLAVSKY UNIVERSITY OF SHUMEN, SHUMEN 9712, 115, UNIVERSITETSKA STR., E-MAIL: j.jordanova@shu.bg
[2]INDUSTRIAL DESIGN DEPARTMENT, AGRARIAN AND INDUSTRIAL FACULTY, "ANGEL KANCHEV" UNIVERSITY OF RUSE, E-MAIL: doichinov@uni-ruse.bg
[3]DEPARTMENT OF MANUFACTURING ENGINEERING AND MACHINE TOOLS, FACULTY OF MANUFACTURING ENGINEERING AND TECHNOLOGIES, TECHNICAL UNIVERSITY OF VARNA, E-MAIL: s_vachinska@tu-varna.bg
[4]DEPARTMENT OF ENGINEERING LOGISTICS, FACULTY OF TECHNICAL SCIENCES, KONSTANTIN PRESLAVSKY UNIVERSITY OF SHUMEN, SHUMEN 9712, 115, UNIVERSITETSKA STR., E-MAIL: n.yordanov@shu.bg

ABSTRACT: *The rapid advancement of modern science and technology demands that engineering professionals possess not only technical expertise but also the ability to effectively manage the human factor within logistics processes. This article explores the role of ergonomics as a strategic tool in engineering logistics for optimizing workflows, enhancing safety and efficiency, and fostering sustainable models in engineering education. The study examines the interconnection between the physical, cognitive, and organizational dimensions of ergonomics and their impact on logistics activities. It presents practical methods for integrating ergonomic principles into engineering systems through digital technologies such as virtual simulation, artificial intelligence, and the internet of things. Case studies from leading companies, including Siemens, Toyota, and DHL, illustrate the tangible benefits of ergonomic applications in logistics environments. The paper emphasizes the importance of incorporating ergonomics into strategic management and engineering curricula to build interdisciplinary competencies. Ultimately, the integration of ergonomic design with digital transformation offers a pathway toward intelligent, human-centered, and sustainable engineering logistics systems.*

KEY WORDS: *Ergonomics, Engineering logistics, Digital technologies, Human factor, Efficiency, Occupational safety.*

Introduction

The rapid development of modern science and technology requires engineering professionals not only to possess technical knowledge but also to have the ability to manage the human factor in logistics processes.

This scientific article examines the application of ergonomics in engineering logistics as a tool for optimizing work processes, improving safety and efficiency, and building sustainable models for engineering education. The study analyzes the relationship between the physical, cognitive, and organizational aspects of ergonomics and logistics activities, presenting practical approaches for integrating ergonomic principles into engineering systems.

Chapter 1. Theoretical Foundations of Ergonomics and Engineering Logistics

Ergonomics as a Multidisciplinary Science

The Nature of Ergonomics

Ergonomics is a scientific discipline that studies humans, their work activity, and their interaction with the environment, machines, tools and technology. Its main goal is to optimize the relationship between humans and the work system by combining principles from physiology, psychology, engineering, and design [8].

According to the International Ergonomics Association (IEA), ergonomics can be divided into three main branches: physical, cognitive, and organizational ergonomics (Table 1) [9].

Table 1 Main branches of ergonomics and their application in engineering logistics

Branch	Research focus	Application in logistics
Physical ergonomics	Biomechanics, working postures, workload	Design of workstations and equipment
Cognitive ergonomics	Perception, attention, decision-making	Optimization of interfaces and control systems
Organizational ergonomics	Communication, team management, scheduling	Improving coordination and process planning

The Nature of Engineering Logistics

Engineering logistics integrates the processes related to the provision, maintenance, and optimization of material and information flows in engineering systems. It includes planning, analysis, and resource management, aiming for efficiency and sustainability in production and operational processes [3].

Effective engineering logistics requires a combination of technological and human competencies. This is where ergonomics plays a key role - ensuring safe and comfortable working conditions, reducing physical and mental strain, and increasing the productivity of engineering personnel.

The Interconnection between ergonomics and engineering logistics

The relationship between ergonomics and engineering logistics lies in their shared goal of optimizing human–system interaction. While logistics focuses on the effective movement of materials, resources, and information, ergonomics ensures that these processes are performed efficiently and safely by humans.

In logistics operations-such as warehouse management, transportation planning, and equipment maintenance-ergonomic principles help design tasks, workstations, and decision-support tools that match human capabilities and limitations. Poor ergonomic design can lead to fatigue, human error, and system inefficiencies, whereas well-integrated ergonomic systems enhance performance, reduce operational costs, and prevent workplace injuries.

From a systemic perspective, ergonomics in logistics supports:

- **Process optimization**, by aligning human performance with workflow design;
- **Safety and reliability**, through risk assessment and human-centered design;
- **Sustainability**, by reducing health-related absenteeism and turnover;
- **Innovation**, by fostering adaptive systems that integrate digital technologies such as IoT, VR/AR, and AI.

This interconnection demonstrates that ergonomics is not an isolated discipline but a core component of modern engineering logistics, shaping how humans and technologies coexist in complex operational environments.

Methodological Approaches to Studying Ergonomics in Logistics Systems

The study of ergonomics in engineering logistics requires a combination of quantitative and qualitative research methods to analyze both technical efficiency and human well-being. Methodological approaches generally include the following dimensions:

1. **Analytical Methods** – Used to evaluate physical and cognitive workload through metrics such as energy expenditure, task duration, error rates, and reaction times.
   Tools like posture analysis (RULA, REBA, OCRA, INSHT), biomechanical modeling, and time–motion studies are widely applied in logistics environments.
2. **Simulation and Modeling** – Virtual and digital twin models enable researchers to simulate logistics processes and predict ergonomic risks before implementation. This method integrates real-time data from

sensors, motion capture, and IoT systems to optimize workstation design and process flow.

3. **Experimental Studies** – Controlled experiments in laboratory or industrial settings help test ergonomic interventions, such as adjusting workstation height, lighting conditions, or user interfaces, to measure their effect on performance and safety.
4. **Human–Machine Interaction (HMI) Analysis** – Focuses on cognitive ergonomics and usability testing of control panels, dashboards, and software interfaces used in logistics management and automation.
5. **Survey and Observation Methods** – Questionnaires (NMQ-Nordic Musculoskeletal
6. Questionnaire), interviews, and field observations provide qualitative data about worker satisfaction, perceived workload, and organizational culture. This helps identify psychosocial and organizational ergonomic factors.
7. **Integrated Evaluation Frameworks** – Modern ergonomics applies hybrid models combining physical, cognitive, and organizational data to create a holistic assessment of logistics performance and human well-being.

Applying these methodologies ensures that ergonomic principles are scientifically validated and practically adaptable to diverse engineering logistics contexts.

Chapter 2. Application of Ergonomics in Engineering Logistics

The Human Factor in Logistics Processes

The human factor remains a critical determinant of efficiency and safety in engineering logistics systems. Despite significant advances in automation, robotics, and artificial intelligence, humans continue to perform essential functions in supervision, control, decision-making, and system maintenance. The quality of these functions directly depends on how well the work environment, tools, and processes are adapted to human capabilities and limitations.

Research in industrial and logistics systems demonstrates that neglecting ergonomic principles leads to physical strain, cognitive overload, and increased risk of human error [5]. Such conditions not only endanger workers' health but also reduce system reliability, leading to costly operational disruptions.

Ergonomic design helps mitigate these risks by improving the interface between humans and logistics systems. For instance:

- Physical ergonomics reduces musculoskeletal strain by optimizing workstation height, lifting frequency, acceptable weight of load and tool design.
- Cognitive ergonomics enhances attention and decision-making through clear interfaces, intuitive controls, and appropriate feedback mechanisms.

- Organizational ergonomics improves team coordination, workload distribution, and shift planning, fostering both efficiency and well-being. **(Fig.1)**

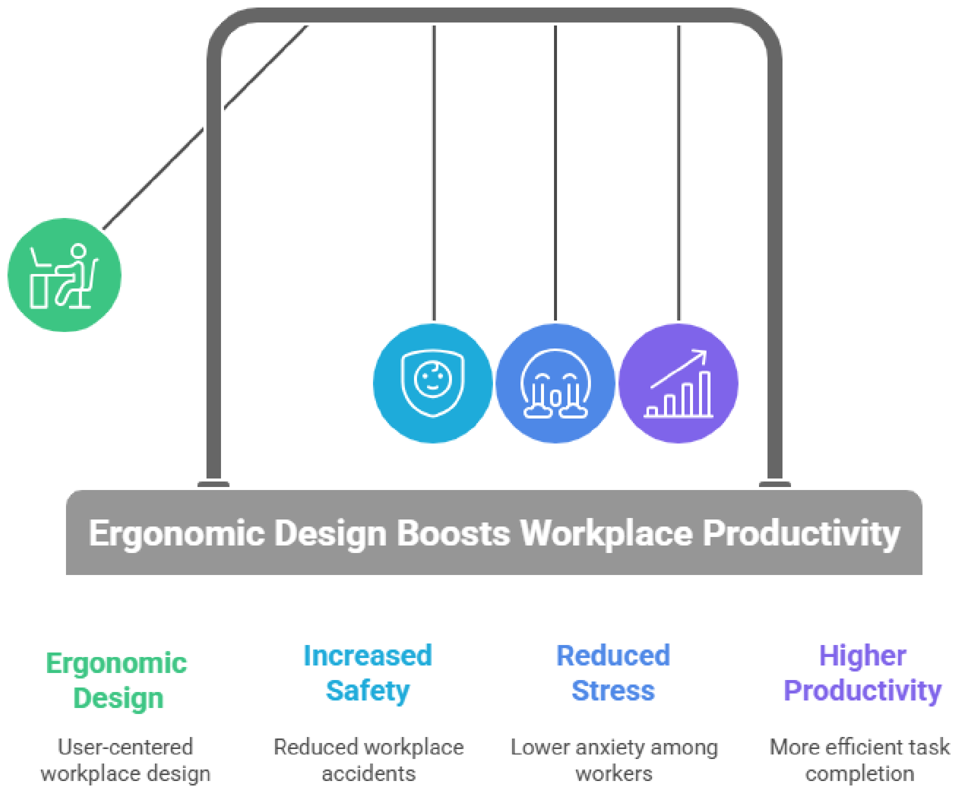

Fig. 1. Relationship between ergonomic factors and logistics performance

Studies indicate that ergonomic interventions can increase logistics productivity by up to 20–25% and reduce workplace accidents by more than 30%.[10]

Furthermore, organizations that integrate human-centered design principles report lower staff turnover and higher employee satisfaction, confirming the direct link between ergonomics and organizational sustainability.

In practice, ergonomic optimization in logistics involves evaluating human performance metrics such as task duration, error frequency, and fatigue indicators. Continuous improvement cycles - including observation, feedback, redesign, and reassessment - ensure that logistics systems remain adaptive and human-centered over time.

The Impact of Digital Technologies

The ongoing digital transformation of industry, often referred to as Industry 4.0, provides unprecedented opportunities for applying ergonomics within engineering logistics. Digital tools and data-driven approaches make it possible to analyze human performance, model work systems, and identify risks with precision that was previously unattainable.

Virtual and Augmented Reality (VR/AR) systems enable engineers to simulate logistics environments and evaluate ergonomic conditions before physical implementation. Through immersive visualization, designers can detect posture issues, spatial inefficiencies, and visibility limitations in warehouse layouts or production cells.

Similarly, digital twins-virtual replicas of real logistics systems-allow for continuous ergonomic monitoring. By integrating data from IoT sensors, these models provide real-time insights into temperature, lighting, vibration, and operator workload, helping organizations optimize both safety and comfort [2].

Artificial Intelligence (AI) plays a growing role in ergonomic assessment by automating data analysis and detecting risk patterns in worker movement, fatigue levels, or reaction times. Machine learning algorithms can identify early indicators of strain or overload, enabling proactive interventions before accidents occur. (Figure 2)

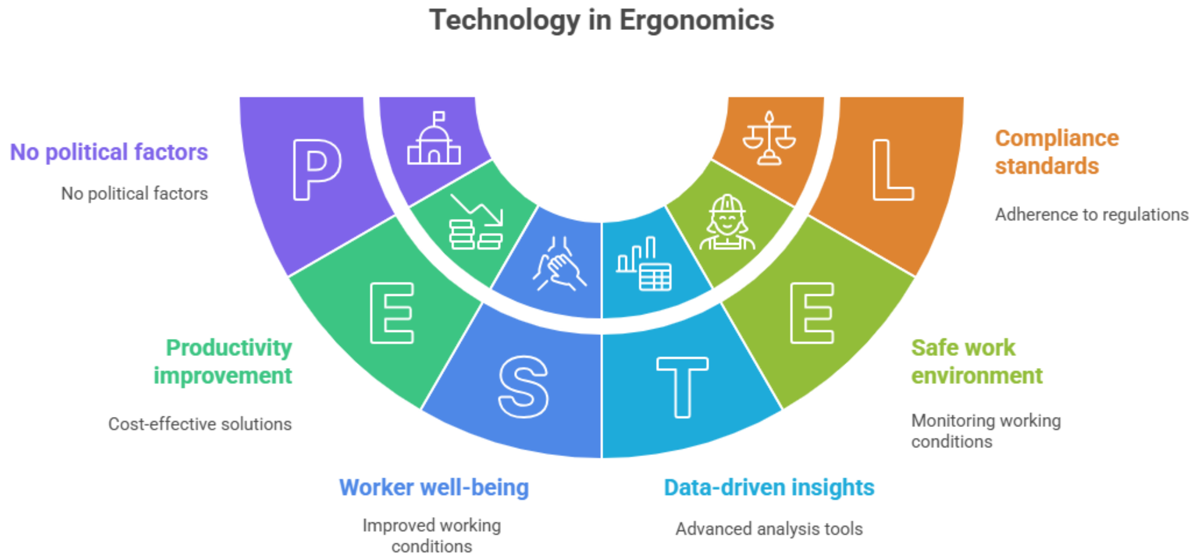

Fig. 2. Integration of digital technologies in ergonomic assessment

Key digital applications in ergonomic logistics include:

- **IoT-based monitoring** of posture, movement, and environmental factors using wearable sensors;
- **AI-driven predictive models** for injury prevention and workload balancing;
- **VR/AR training programs** for safe equipment operation and spatial awareness;
- **Robotic collaboration systems (cobots)** that assist with heavy lifting and repetitive tasks, reducing physical stress on workers.

The integration of these technologies leads to smart ergonomics-a concept combining data analytics, automation, and human-centered design to create adaptive logistics systems. Such systems continuously learn from human behaviour and environmental data to improve both productivity and employee well-being.

Practical Examples and Best Practices

A number of global organizations have successfully implemented ergonomic principles supported by digital tools, setting benchmarks for best practice in engineering logistics.

- Siemens AG employs simulation models for evaluating operator workload during equipment maintenance and assembly. Using digital twins, the company analyzes task sequences, reachability, and body posture to redesign workstations for maximum efficiency and minimal strain [13].
- Toyota Motor Corporation integrates ergonomics into its famous *Toyota Production System (TPS)*. Operators participate actively in process design and ergonomic assessment, supported by VR-based training environments that allow safe practice and evaluation of movement efficiency before real-world application [14].
- DHL Supply Chain implements wearable exoskeletons that support the back and lower limbs during lifting operations. These devices reduce muscle fatigue and the risk of injury while maintaining operational speed. The company also uses AI-driven analytics to monitor ergonomic compliance in real time [4].
- Amazon Robotics combines automation with ergonomic workstation design in its fulfillment centers. Human operators are assigned tasks that best match their skill levels and physical capacity, reducing repetitive strain injuries while maintaining high throughput [1].

These examples illustrate how ergonomics has evolved from a supportive discipline to a strategic management tool. When embedded into organizational culture, ergonomic thinking transforms logistics operations into systems that are simultaneously efficient, sustainable, and humane.

Ergonomic Risk Assessment and Performance Metrics

Effective implementation of ergonomics in logistics requires systematic risk assessment and performance evaluation. Several standardized methods and analytical tools are used to identify ergonomic hazards and quantify their impact on worker health and system performance.

1. Physical Risk Assessment Tools

- **RULA (Rapid Upper Limb Assessment)** and **REBA (Rapid Entire Body Assessment)** evaluate body posture, forced position, repetitive

movement and muscular load in logistics activities such as lifting, packing, and material handling.
- **NIOSH Lifting Equation** helps determine safe weight limits for manual handling tasks.
- **OWAS (Ovako Working Posture Analysis System)** assesses postural risks in repetitive movements [12].

2. Cognitive and Mental Workload Evaluation

Techniques such as NASA-TLX (Task Load Index) and eye-tracking systems measure cognitive strain and visual attention during monitoring or control tasks. In logistics control rooms or warehouse navigation, these analyses help optimize interface design and reduce decision fatigue [11].

3. Environmental and Organizational Factors

Quantitative metrics-like noise levels, lighting intensity, temperature, and task rotation frequency-are correlated with fatigue indicators and absenteeism rates. Organizational surveys capture psychosocial dimensions such as job satisfaction, perceived autonomy, and teamwork quality.

4. Integrated Ergonomic Performance Index (EPI)

Modern logistics systems adopt composite indices combining physical, cognitive, and organizational parameters. This integrated approach allows continuous tracking of ergonomic efficiency alongside traditional logistics indicators (e.g., throughput time, error rate, energy use) (Table 2).

Table 2. Ergonomic performance metrics in logistics systems

Category	**Typical Metrics**	**Example Application**
Physical workload	Lifting index, posture score, muscular fatigue	Manual handling, assembly lines
Cognitive workload	NASA-TLX, eye-tracking, error rate	Control systems, data analysis tasks
Organizational efficiency	Communication delay, coordination time, job satisfaction	Shift planning, team management

By combining these metrics with digital monitoring systems, logistics engineers can build adaptive feedback loops-automatically identifying high-risk operations and generating recommendations for redesign or training.

Integration Challenges and Implementation Barriers

Despite the clear advantages of ergonomics, its integration into engineering logistics still faces several challenges:
- **Financial constraints**, as ergonomic technologies and digital tools often require initial investment and specialized training;

- **Cultural resistance**, where organizations prioritize short-term productivity over long-term health benefits;
- **Lack of interdisciplinary expertise**, since ergonomics spans engineering, psychology, and management;
- **Data privacy and ethics**, concerning the use of wearable and AI-based monitoring systems;
- **Fragmented evaluation frameworks**, making it difficult to link ergonomic data with overall logistics performance indicators.

To overcome these barriers, organizations must adopt a strategic, top-down approach to ergonomics implementation-supported by leadership commitment, continuous training, and cross-departmental collaboration.

Chapter 3. Prospects for Development and Integration of Ergonomics in Engineering Logistics

The Need for Strategic Implementation

The integration of ergonomics into engineering logistics must be viewed as a strategic and systemic process, not a one-time improvement project. Ergonomic design influences every level of logistics management - from workstation layout to long-term corporate sustainability policies. For this reason, ergonomics should be embedded into the strategic management framework of engineering organizations as a continuous process of assessment, adaptation, and innovation [6].

Strategic implementation begins with the establishment of ergonomic standards and policies that align with the organization's operational goals, safety regulations, and sustainability targets. These standards should be integrated into all stages of the logistics system life cycle, including:

- Design and planning - ergonomic principles incorporated during the layout and workflow design of warehouses, transport routes, and production lines;
- Operation and monitoring - continuous assessment of human performance, fatigue, and comfort using real-time digital monitoring tools;
- Evaluation and feedback - systematic review of ergonomic indicators to refine processes and improve work conditions.
- Data archiving – creating a streamlined system for storing and organizing information, allowing for seamless replacement of team members

A successful ergonomic strategy relies on leadership commitment and the active involvement of employees at all organizational levels. Top management must allocate resources for ergonomic research, training, and technology acquisition, while middle management should ensure the practical integration of ergonomic solutions in daily logistics activities.

Moreover, ergonomic strategy contributes to corporate social responsibility (CSR) and sustainability goals. By promoting worker safety, health, and satisfaction, organizations demonstrate ethical responsibility and build a positive corporate image, which in turn enhances competitiveness and employee retention.

Ultimately, the implementation of ergonomics as a strategic component of engineering logistics transforms the traditional view of the worker from a resource to be managed into a central element of value creation in modern industrial systems.

Education and Interdisciplinary

Education plays a pivotal role in preparing future engineers and logistics specialists capable of applying ergonomic principles in complex industrial environments. The growing digitalization of logistics systems demands that professionals possess both technical proficiency and human-centered analytical skills. For this reason, ergonomics must be introduced as a core component of engineering and logistics education.

Universities and technical institutes can implement ergonomics education through:

- **Dedicated courses** on human factors, safety engineering, and workplace design;
- **Simulation laboratories** where students analyze real logistics systems and assess ergonomic risks using digital tools such as VR, AR, and digital twins;
- **Collaborative projects** that bring together students from engineering, industrial design, management, and health sciences to develop interdisciplinary solutions.

This interdisciplinary educational model fosters a new generation of engineers who are not only technologically skilled but also socially and ethically aware of the human dimension in industrial processes.

Furthermore, lifelong learning and professional training are equally essential. Companies should organize regular training programs for logistics managers, engineers, and operators on ergonomics assessment, human–machine interaction, and safe work practices. The combination of theoretical education and practical training supports a culture of continuous improvement, where ergonomics becomes a natural part of problem-solving and innovation.

Collaboration between academia, industry, and professional associations is also key to promoting research-driven ergonomics. Joint projects, internships, and applied research initiatives help translate academic findings into practical industrial solutions, ensuring that ergonomic innovation keeps pace with technological change.

Social and Health Aspects

The social and health dimensions of ergonomics in engineering logistics extend far beyond physical safety-they encompass overall worker well-being, motivation, and organizational culture. An ergonomically designed workplace contributes to both physical health (through reduced strain, fatigue, and injury) and mental health (through reduced stress, cognitive load, and emotional burnout) [16].

Work-related musculoskeletal disorders (WMSDs), repetitive strain injuries, and chronic fatigue are among the most common health issues in logistics operations involving manual handling or repetitive tasks. Ergonomic interventions-such as adjustable workstations, exoskeletons, and automation of hazardous processes-significantly reduce these risks.

At the organizational level, ergonomics also enhances social cohesion and morale. Workers who feel safe and valued are more motivated, communicate better, and show higher levels of engagement and loyalty. This leads to measurable organizational benefits such as lower absenteeism, reduced turnover, and improved productivity (Fig.3).

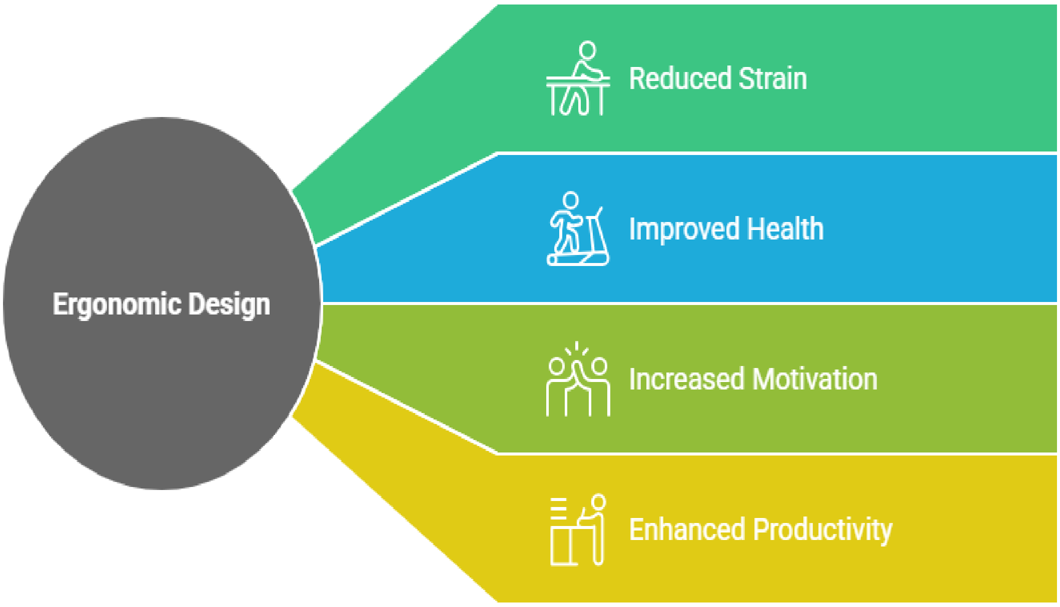

Fig. 3. Relationship between ergonomics, health, and productivity

Psychosocial ergonomics further highlights the importance of factors such as work–life balance, communication, and employee autonomy. Effective team organization, transparent communication, and participatory decision-making contribute to a healthy organizational climate where workers actively engage in continuous improvement initiatives.

From a societal perspective, ergonomic investment contributes to public health and economic sustainability. Fewer workplace accidents and occupational diseases reduce healthcare costs and increase national productivity. Hence, ergonomics is not only an internal organizational concern but also a significant component of social development and workforce resilience.

Future Trends and Digital Transformation

The future of ergonomics in engineering logistics is inseparably linked to the ongoing digital transformation of industry, marking the transition toward Industry 5.0, where human-centric innovation stands at the core of technological progress [7]. Emerging technologies provide new tools for analyzing, predicting, and enhancing human performance within logistics systems [15].

1. Artificial Intelligence and Predictive Analytics

AI algorithms enable predictive ergonomic analysis by identifying risk factors before they lead to injury or error. Machine learning models can process vast amounts of sensor and video data to evaluate posture, workload, and stress in real time, offering immediate recommendations for corrective actions.

2. Internet of Things (IoT) and Wearable Technology

IoT-based ergonomic monitoring systems integrate data from wearable devices, cameras, and environmental sensors. This allows continuous assessment of ergonomic parameters such as temperature, humidity, lighting, vibration, and movement. Wearable exoskeletons and smart gloves not only reduce physical strain but also provide real-time feedback to workers.

3. Augmented and Virtual Reality (AR/VR)

AR and VR applications are increasingly used for training, process visualization, and design validation. Operators can undergo immersive simulations of logistics tasks, learning optimal movement patterns and safety procedures in risk-free virtual environments. AR headsets assist operators with visual instructions, navigation, and maintenance support.

4. Digital Twins and Human-Centered System Simulation

Digital twins offer a revolutionary approach to ergonomics by integrating physical and virtual systems into a unified model. They allow engineers to simulate complex logistics networks, evaluate ergonomic performance under different scenarios, and test modifications before physical implementation. The inclusion of human factors data within digital twins promotes the creation of adaptive, intelligent systems capable of self-optimization based on human feedback.

5. Integration of Sustainability and Ergonomics

Future logistics systems will increasingly combine environmental sustainability with ergonomic design. Energy-efficient lighting, climate control, and eco-friendly materials can improve both worker comfort and environmental performance. Sustainable ergonomics thus aligns with global goals such as the United Nations Sustainable Development Goals (SDGs), particularly SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation, and Infrastructure) [15].

The convergence of these technologies signifies a paradigm shift-from ergonomics as a corrective tool to ergonomics as a predictive, adaptive, and integrative framework. The result is a new model of engineering logistics that prioritizes human well-being alongside productivity and innovation.

Conclusion

The interdisciplinary view on these topics reduces that ergonomics is not only a solved organizational problem, but also an important component of social development and workforce sustainability on the way to offering high-quality services in engineering logistics.

The integration of ergonomics into engineering logistics represents a fundamental step toward building safer, smarter, and more sustainable industrial systems. By aligning human capabilities with technological progress, ergonomics ensures that the growing complexity of logistics operations does not compromise human health or efficiency.

Digital technologies-AI, IoT, VR/AR, and digital twins-open new horizons for ergonomics, allowing real-time assessment, predictive modeling, and intelligent system adaptation. However, their success depends on strategic planning, education, interdisciplinary collaboration, and ethical governance.

In the long term, ergonomics should be recognized as a strategic management tool-not merely a support function-essential for achieving competitiveness, innovation, and social responsibility in the modern engineering landscape. Placing the human being at the center of logistics design and decision-making will define the next era of engineering excellence and industrial sustainability.

Acknowledgments

This scientific article under project number RD-08-123/07.02.2025 „Research on the application of ergonomics in activities related to engineering logistics“ is funded.

References:

[1] Amazon Robotics. (2022). Safety and Ergonomics Overview. Retrieved from https://www.aboutamazon.com (Last accessed on 11 October 2025).

[2] Battaïa, O., & Delorme, X. (2020). Ergonomic design and digital twin technology in manufacturing systems. Procedia Manufacturing, 51, 1041–1048.

[3] Christopher, M. (2016). Logistics & Supply Chain Management (5th ed.). Pearson Education Limited.
[4] DHL Supply Chain. (2021). Innovation Report: Robotics and Exoskeletons in Logistics. Retrieved from https://www.dhl.com (Last accessed on 11 October 2025).
[5] Dul, J., & Weerdmeester, B. (2008). Ergonomics for Beginners: A Quick Reference Guide (3rd ed.). CRC Press.
[6] European Agency for Safety and Health at Work (EU-OSHA). (2019). The Future of Work: Digitalisation and Occupational Safety and Health. Publications Office of the European Union.
[7] European Commission. (2021). Industry 5.0: Towards a Sustainable, Human-Centric and Resilient European Industry. Luxembourg: Publications Office of the European Union.
[8] Helander, M. G. (2006). A Guide to Human Factors and Ergonomics (2nd ed.). CRC Press.
[9] International Ergonomics Association (IEA). (2021). Definition and Domains of Ergonomics. Retrieved from https://iea.cc (Last accessed on 11 October 2025).
[10] Karwowski, W., & Marras, W. S. (1999). The Occupational Ergonomics Handbook. CRC Press.
[11] NASA. (1988). Task Load Index (NASA-TLX) – Paper and Pencil Package. NASA Ames Research Center, Moffett Field, CA.
[12] National Institute for Occupational Safety and Health (NIOSH). (2017). Workplace Safety and Health Topics: Ergonomics and Musculoskeletal Disorders. Retrieved from https://www.cdc.gov/niosh/topics/ergonomics (Last accessed on 11 October 2025).
[13] Siemens AG. (2020). Digital Industries: Human-Centered Manufacturing Report. Retrieved from https://www.siemens.com (Last accessed on 11 October 2025).
[14] Toyota Motor Corporation. (2019). Sustainability Data Book. Retrieved from https://global.toyota/en/sustainability/ (Last accessed on 11 October 2025).
[15] United Nations. (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations General Assembly.
[16] World Health Organization (WHO). (2020). Occupational Health: A Manual for Primary Health Care Workers. WHO Press.