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A Study on Continuous Adaptation and Innovation Through Technology and Ergonomics to Improve Health and Safety at Work

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Abstract – Many sectors, including occupational health and safety, are significantly impacted in today's rapidly evolving technological landscape. Companies are increasingly compelled to integrate innovative technologies to address emerging challenges. Technology plays a crucial role in enhancing employee safety and health, from advancements in protective equipment to implementing sophisticated monitoring and accident prevention systems. Additionally, the integration of ergonomic solutions, driven by technological advancements, further contributes to optimizing workplace safety and improving overall well-being.

Keywords: ergonomics, internet of things, health and safety, occupational health and safety, technology.

I. INTRODUCTION

In recent decades, workplaces have undergone major changes and health and safety issues have diversified considerably. Employers now face not only traditional risks such as accidents and exposure to hazardous substances, but also new challenges such as work-related stress and illnesses caused by modern technologies. These constant changes have created an urgent need for innovative solutions and continuous adaptation to ensure a safe and healthy working environment for all employees [1].

This article explores how innovative technologies can be integrated into occupational health and safety strategies, with a special focus on ergonomics as a starting point. We discuss the concrete benefits of these technologies as well as the associated challenges and ethical dilemmas. Through relevant case studies and practical examples, the article will emphasize both the potential of these technologies to improve the safety and health of employees and the need for a well-thought-out and strategic approach to their implementation.

II. EMERGING TECHNOLOGIES IN OCCUPATIONAL SAFETY AND HEALTH

In the field of occupational safety and health, emerging technologies play a crucial role in improving working conditions and preventing accidents. These include artificial intelligence (AI), the Internet of Things (IoT), augmented reality (AR) and collaborative robots. AI and IoT enable continuous monitoring of the work environment and early risk detection. Augmented reality provides interactive training and simulations of dangerous scenarios, and collaborative robots can take over dangerous tasks, reducing employees' exposure to risks. Even offering a straightforward software solution that allows employees to easily access information about potential risks with just one click constitutes a significant advancement in the field of occupational safety and health. These technologies contribute significantly to creating a safer and healthier work environment while optimizing operational efficiency [2].

Going in deep with the literature review, there have been underlined that emerging technologies in occupational safety and health (OSH) are transforming how workplaces manage risks and ensure worker well-being. These technologies, driven by advancements in Industry 4.0, include wearable sensors, extended reality, exoskeletons, applied observability, digital twins, and digitalization in health programs. Each of these innovations offers unique benefits and challenges, contributing to a safer and more efficient work environment.

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The main developments supported by the literature are:

- Wearable Sensors and Extended Reality provide real-time monitoring of workers' health and safety, alerting them to potential hazards and reducing onsite injury risks. These sensors can track vital signs and environmental conditions, offering immediate feedback [3, 4].
- Extended reality technologies, such as virtual reality (VR) and augmented reality (AR), enhance safety training by simulating realistic scenarios without exposing workers to actual hazards. This immersive training can improve hazard recognition and response skills [3].
- Exoskeletons and Robotics are being integrated into workplaces to reduce physical strain and injury risks, particularly in physically demanding tasks. These technologies assist workers in lifting heavy objects and performing repetitive tasks, thereby minimizing ergonomic hazards [3].
- Applied Observability is an emerging approach that shifts occupational health and safety from a reactive to a predictive model. By continuously monitoring and analyzing data, organizations can identify potential hazards and improve safety practices proactively [5].
- Digital Twins, which are digital replicas of physical assets, offer a novel way to enhance workplace safety. They enable the simulation and analysis of work environments, helping to identify risks and optimize safety measures. However, creating human-focused digital twins is complex and requires sophisticated integration of hardware and software [6].
- Digitalization in Health Programs facilitates risk assessments, fitness evaluations, and health surveillance. Technologies like telemedicine and advanced diagnostic tools enable early detection of work-related illnesses, improving overall worker health and productivity [7, 8].

While these technologies offer significant advancements in OSH, they also present challenges such as integration complexity, data privacy concerns, and the need for cross-generational collaboration to overcome technological adoption barriers. Addressing these challenges is crucial for maximizing the benefits of these emerging technologies in occupational safety and health.

III. BENEFITS OF TECHNOLOGICAL INNOVATION IN OCCUPATIONAL SAFETY AND HEALTH IN ROMANIA

The implementation of innovative occupational health and safety technologies offers multiple benefits, contributing to increased safety, efficiency and comfort for employees. Here are some of the main benefits [9]:

A. Reducing accidents and preventing risks

Automated monitoring and alerting are made possible by IoT and AI technologies, which enable real-time tracking of working conditions and the rapid identification of risks. Sensors and machine learning algorithms can detect issues like toxic spills or unsafe working environments and send immediate alerts to the security team. Minimizing accidents involves utilizing collaborative robots (cobots) and advanced protective gear to eliminate hazardous tasks for workers. This approach not only lowers the risk of accidents but also enhances employee morale and job satisfaction. For instance, in automotive manufacturing, cobots handle repetitive and risky tasks, such as managing heavy components, which helps to reduce incidents related to manual handling.

B. Increasing efficiency and productivity

Enhancing work processes involves leveraging new technologies like AI and augmented reality to boost efficiency and minimize downtime. AI systems analyze operational data to identify opportunities for process improvements and automate repetitive tasks, resulting in higher productivity. In terms of employee comfort and safety, health monitoring technologies such as smart wristbands or biometric sensor headsets play a crucial role. These devices allow for early detection of potential health issues, enabling swift interventions and preventing accidents. For instance, in the construction sector, smart bracelets track vital signs and alert the first aid team if signs of illness or fatigue are detected.

C. Improving occupational safety training and education

Interactive training and realistic simulations are revolutionized by augmented and virtual reality, which turns security training into an engaging and lifelike experience. This approach allows employees to practice emergency scenarios safely, significantly enhancing information retention and crisis preparedness. In addition, mobile apps and AR solutions offer employees immediate access to information and guidance directly on their devices. This capability aids in adhering to safety procedures and accelerates emergency response.

D. Improving communication and collaboration

Advanced communication and collaboration platforms, including cloud-based solutions and integrated communication tools, facilitate swift information sharing and effective coordination between security teams and employees. Furthermore, continuous monitoring systems and real-time feedback offer valuable insights to both employees and management, supporting ongoing improvements in occupational health and safety practices.

IV. CHALLENGES AND CONSIDERATIONS IN TECHNOLOGY DEPLOYMENT IN ROMANIA

Enterprise integration is the use of technology and methodologies to tightly connect everything in an IT landscape - including applications, data, cloud, cloud, APIs, processes, and devices. It combines multiple integration approaches into one combined effort with a governance model.

The implementation of emerging technologies in Romania faces several specific challenges, reflecting the country's general difficulties in software adoption compared to other European countries. We will explore these challenges, providing relevant data and graphs to illustrate the situation, thus highlighting the complexity of integrating software solutions in Romania, which implicitly translates into the fact that also in the field of occupational health and safety the adoption of specific software is a real challenge.

As shown in Fig. 1, in 2023, e-business software usage was highest in the Nordic countries and Belgium. Almost half of the enterprises in all sectors (except agriculture, forestry and fishing, mining and quarrying), excluding the financial sector, with 10-49 employees in the European Union have adopted e-business applications (ERP, CRM and/or BI). Among EU countries, the percentage of enterprises using these applications varied significantly: it reached 69.5% in Denmark, 65.8% in Finland and 62% in Belgium, while in Romania it stood at 21.1%, in Bulgaria at 21%, and in Slovakia at 25.3% [10].

In terms of enterprises with 50-249 employees, as depicted in Figure 2, Romania ranked 33.5%, Bulgaria 46.3%, Slovakia 50.9%, Denmark 89.5%, and Finland is the top leader with 91.6% [10].

As illustrated in Figure 3, for companies with more than 250 employees, the situation has changed as follows: Romania was at 58.9%, Bulgaria at 72.3%, Slovakia at 85.6%, and Denmark and Finland tied at 98.6% [9].

Romania has a relatively low adoption of e-business software in all size categories of enterprises, but the difference is more pronounced in small and medium-sized enterprises. This may reflect barriers such as lack of resources, lack of knowledge or lack of confidence in the technological benefits.

It is essential for Romania to invest in digital literacy, IT infrastructure, and supportive policies to encourage the adoption of e-business technologies and improving e-business technology adoption can help Romanian enterprises increase their productivity and competitiveness in the European and global markets. Collaboration between the government and the private sector can facilitate the deployment of e-business solutions, through financial incentives, technical advice, and awareness campaigns.

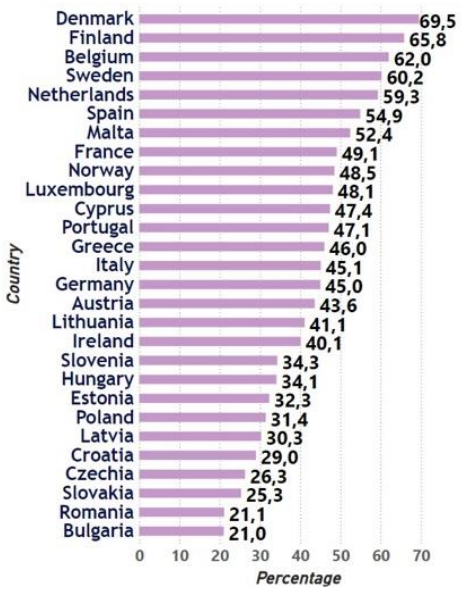

Fig. 1. Companies between 10-49 employees using e-business software (ERP, CRM and/or BI) [10].

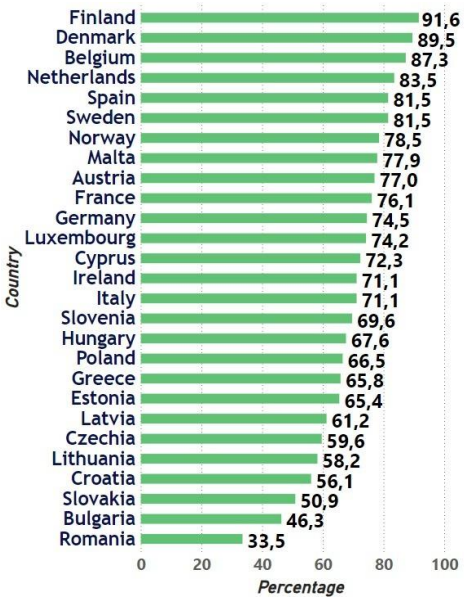

Fig. 2. Companies between 50-249 employees using e-business software (ERP, CRM and/or BI) [10].

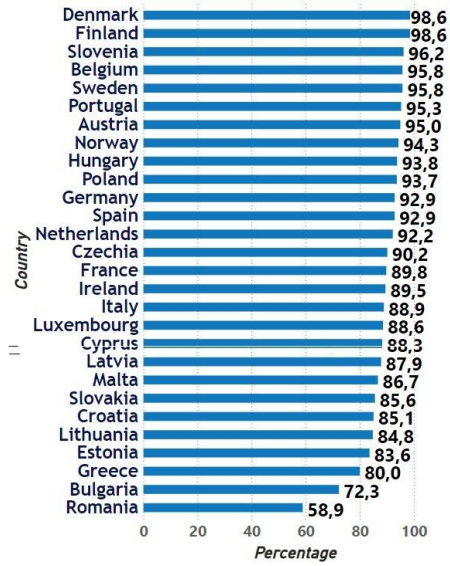

Fig. 3. Companies with more than 250 employees use e-business software (ERP, CRM and/or BI) [10].

Given the data analyzed, a good start for the integration of digitization in the field of OSH (Occupational Health and Safety) could be the area of ergonomics. The implementation of digital solutions in ergonomics can increase technological awareness and adoption, as the improvement of working conditions is directly related to the comfort and health of employees. By demonstrating the tangible benefits of digitization, companies may be encouraged to adopt other digital solutions.

Digital ergonomic solutions can also help to identify and reduce health and safety risks, which can lead to a decrease in workplace accidents and improved productivity. Thus, an initial focus on ergonomics can facilitate a smoother and more accepted transition to full digitization in the EHS sector, benefiting both employees and employers [11].

V. ERGONOMICS AND ITS BENEFITS

Ergonomics is the science of adapting the workplace, equipment and tasks to meet the physical and psychological needs of employees. Well-implemented ergonomics can decrease the risks of accidents and musculoskeletal disorders while improving worker comfort and efficiency [12].

In the digital age, adapting to the needs of remote workers is crucial to maintaining a healthy and safe working environment. One of the most innovative solutions is the integration of ergonomics into a dedicated occupational health and safety (OHS) mobile app. This functionality not only supports employee well-being, but also contributes to a significant increase in productivity and efficiency.

The main benefits of ergonomics include reduced pain and discomfort, increased efficiency and

productivity, improved employee health and well-being, reduced occupational health and safety costs.

The book, *Ikigai*, written by Héctor García and Francesc Miralles, introduces us to the Japanese concept of 'Ikigai', which translates as 'meaning of life' or 'purpose of being'. This philosophy suggests that discovering a purpose in life is essential for living a long, healthy and happy life. Ikigai represents the intersection of what you love, what the world needs, what you can be paid to do and what you do well.

Applying Ikigai principles to occupational health and safety can radically change the way employees perceive and experience working life, namely:

- Finding meaning in work involves creating an environment where employees can discover and pursue personal purpose, blending professional and personal fulfillment in a balanced manner.
- Maintaining a healthy work-life balance is essential for preventing burnout and supporting both mental and physical well-being.

Ergonomics contributes significantly to this balance, improving comfort and productivity at work and thus facilitating finding personal purpose in daily activities.

A dedicated OSH mobile app may also include an ergonomics section, which provides exercise sets customized to the user's work activity. In addition, the app can integrate guided sessions, exercise timers and monthly reports per employee, providing a complete solution for improving health and comfort in the workplace. These exercises are designed to help employees maintain proper posture and an active lifestyle and can be graphically exemplified through images or videos. In addition to the physical benefits, they also contribute to mental well-being, thus supporting finding and maintaining personal purpose (Ikigai). Examples of ergonomic exercises for maintaining an active and healthy lifestyle that can be incorporated into such an application include:

- Stretching fingers and wrists, which improves flexibility and reduces the risk of musculoskeletal disorders.
- Neck and shoulder stretch which can contribute to relaxing tense muscles contribute to general well-being and stress reduction.
- Correct body positioning, by suggesting practical tips and video guides for setting up an ergonomic workspace, promoting a healthier and more balanced working life.

Ergonomic challenges and games that blend fun with health can also be included in the application's development. For example, the following activities could be featured:

- Interactive challenges that may allow the employees to engage in activities that merge ergonomic exercises with enjoyment, encouraging them to adopt healthy routines and explore personal purpose in a fun and stimulating manner.
- Competitions and rewards that may guide the employees to create a dynamic work environment where they are motivated to develop healthy habits and discover their ikigai through interactive activities and rewards [13,14].

Another few main benefits for both the employer and the employee of integrating ergonomics into such OSH Application would be:

- Encouraging a healthy work-life balance helps mitigate the risks of stress and burnout.
- Employees who find purpose in their daily activities tend to be more motivated, productive, and satisfied with their jobs.
- Applying ergonomic principles fosters a positive organizational culture, where employees feel valued and supported [12-14].

VI. CONCLUSIONS AND RECOMMENDATIONS

Continuous Adaptation and Innovation Through Technology and Ergonomics to Improve Health and Safety at Work approach has been opening the way to the Continuous Adaptation and Innovation (CAI) which is a strategic approach that involves the ongoing development and implementation of new technologies and ergonomic principles to enhance workplace health and safety. It recognizes that the workplace is a dynamic environment, and that proactive measures are essential to mitigate risks and protect employees.

Fig. 4. Example of fingers and wrist stretching exercises [15, 16]

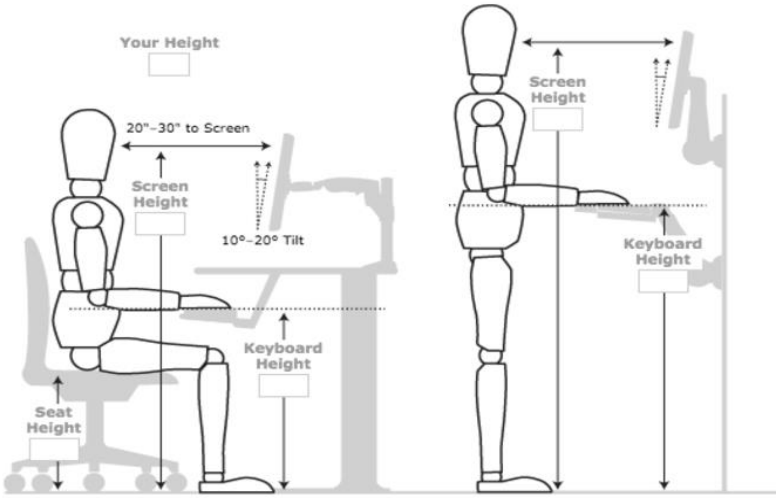

Fig. 5. Practical recommendations on how to adjust home workspaces [17]

Key Components of CAI:

1. Technology Adoption:
- IoT and Wearables: Sensors and wearable devices can monitor real-time conditions, detect hazards, and provide early warnings.
- Automation: Robotic systems can reduce manual labor, preventing repetitive strain injuries and exposure to hazardous substances.
- Virtual and Augmented Reality: These technologies can provide immersive training experiences, simulating dangerous scenarios without risk.
- Data Analytics: Analyzing large datasets can identify trends, predict risks, and inform preventive measures.
2. Ergonomic Design:
- Workplace Assessments: Regular evaluations of workstations and tasks to ensure they are ergonomically sound.
- Adjustable Equipment: Furniture and tools that can be customized to fit individual workers' needs.
- Proper Posture and Movement: Training employees in correct body posture and movement to prevent musculoskeletal disorders.
- Work-Life Balance: Promoting practices like flexible work arrangements and stress management to improve overall well-being.
3. Continuous Improvement:
- Feedback and Evaluation: Gathering input from employees and conducting regular assessments to identify areas for improvement.
- Research and Development: Staying updated on the latest technologies and ergonomic principles.
- Collaboration: Partnering with experts in health and safety, ergonomics, and technology to develop innovative solutions.

Several benefits of CAI have been collected based on our research, both from the actual literature and from practical experience (consulting and education activities):

- Reduced Injuries and Illnesses: Implementing CAI can significantly reduce the occurrence of workplace accidents and health problems;
- Improved Productivity: A safer and healthier workforce leads to increased productivity and reduced absenteeism;
- Enhanced Employee Morale: Employees feel valued and supported when their well-being is prioritized;
- Compliance with Regulations: CAI helps businesses meet regulatory requirements related to health and safety;
- Cost Savings: Preventing injuries and illnesses can result in long-term cost savings.

By embracing continuous adaptation and innovation, organizations can create safer, healthier, and more productive work environments for their employees.

Furthermore, in the context of the present paper, technological innovations such as AI, IoT, augmented reality and virtual reality have significant potential to improve health and safety at work, particularly through implementing digital ergonomic solutions. These technologies help to reduce accidents, increase efficiency and improve training and collaboration within organizations, thus facilitating a safer and healthier working environment. Although Romania ranks last in terms of OSH software integration, there is nevertheless a development trend in this direction. We encourage companies to explore the funding opportunities available through European programs such as the European Social Fund (ESF) and the Competitiveness Operational Programme (POC), as well as government grants dedicated to innovation and digitalization.

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