SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2024
ORGANIZATION AND MANAGEMENT SERIES NO. 210

CMMS CLASS SYSTEM IN INDUSTRY 5.0 ENTERPRISE

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Purpose: The purpose of the article is presenting the conception of using CMMS class systems in supporting maintenance in Industry 5.0 concept.
Design/methodology/approach: The above-mentioned purpose was achieved as research was executed focusing on Industry 5.0 and Society 5.0 ideas and opportunities of their applications in maintenance activities in enterprise.
Findings: During the conducted research, it was found that there is a necessity to integrate CMMS class system with another co-operating computer systems in which it is required to implement model solutions guaranteeing existence of humanocentric character of computer tool, sustainable development in maintenance of technical means and also resilience in this area.
Research limitations/implications: The article shows the conception of application of CMMS class system when Industry 5.0 conception is development. Since the article only presents an outline of the concept, it is necessary to continue work in this area, in particular by developing qualitative and quantitative models, as well as measures for assessing processes and systems in the company, based on which it will be possible to determine whether the implementation of a CMMS class system meets the requirements are the criteria: human-centricity of technical systems, sustainable development and resilience.
Practical implications: The presented research resulting in the concept can be used in (long-term) planning of the development of an enterprise or in scientific and research activities focused on the future of societies and the technical means that they use.
Social implications: Conducting a research using the method proposed in the article it is possible to convince people interested in it that there are needs and possibilities - means and methods for environmental protection and ensuring human well-being.
Originality/value: The methodology presented in the article is original and is addressed to employees of maintenance departments interested in implementing new solutions - methods and tools, as well as creators of CMMS systems and people who implement them.
Keywords: exploitation, maintenance, management, CMMS, Industry 5.0, Society 5.0.
Category of the paper: Research paper.

1. Introduction

Modern civilization faces various challenges. Many of them are related to the functioning of the technosphere, the elements of which are technical means, and the occurrence of negative consequences of its impact on the ecosphere. For this reason, human life on Earth is at risk. This causes the company to take actions that will reduce or eliminate the impact of undesirable phenomena on the future of subsequent generations. As an antidote to these problems, technical and organizational solutions resulting from the Industry 4.0 concept, which is now increasingly widely implemented in enterprises, are increasingly used. Care for the environment goes hand in hand with reflection on the needs of the quality of life of society's representatives, an increasing number of whom will belong to the group of older people.

Therefore, the topic of Industry 5.0 becomes the subject of discussion in the scientific community and among practitioners, which, complementing the assumptions of Industry 4.0, pays special attention to the human-technical relationship. In the light of its goals, there is a need for a sustainable approach to operation and maintenance. By confronting the assumptions of the Industry 4.0 concept with the theses of Society 5.0 and Industry 5.0, it is possible to increase the quality of life in societies where the number of older people is increasing and will increase in the future. The adoption of the mentioned ideas for solving the problems discussed in the article will include, among others, the development and implementation in enterprises of means and methods supporting decision-making that meet technical, organizational, economic, environmental and social criteria. These include CMMS systems that support operation and maintenance management in the enterprise. The development of models describing phenomena in the human-technical means relationship and their implementation in systems of this class creates a chance to achieve the goals that are the subject of the author's interest in the publication.

Therefore, in the article, in addition to the characteristics of the discussed industry concepts, attention was paid to the challenges faced by Industry 5.0 enterprises. An outline of how to support maintenance management in such an enterprise is presented. The possibilities offered by their implementation and development for CMMS systems and their integration with other ones, carried out at the methodological and tool level, were shown.

2. The philosophy of Industry 5.0 and its possibilities – literature research

2.1. Industry 5.0 – introduction

Industry 5.0 is the result of the activities of the European Union, which in 2021 published the so-called policy briefs. In this document, Industry 5.0 is shown as a stage in the development of enterprises, in which special attention is paid to social and environmental issues and combining advanced technologies (which are elements of the 4.0 philosophy with human needs). The technologies mentioned include (Fidali, 2021):

- machine learning,
- artificial intelligence,
- advanced data management systems,
- simulation models and digital twins.

The most important issues of interest to researchers of the Industry 5.0 concept include (Kaasinen et al., 2022; Leng et al., 2022; www.PrzemyslPrzyszlości.gov.pl):

- human-centricity – the most important goal of the company is no longer to improve the effectiveness and efficiency of production, but the well-being, competences and development of employees. The question: how can employees use new technology? In the concept of Industry 4.0, the key question becomes: what can technology do for employee. By performing tasks (with humans), robots can achieve the goal of providing assistance to people and improving their quality of life;
- sustainability – circular resource management meets the need to reduce the impact of enterprises on the environment. Other changes resulting from the assumptions of the sustainable development policy and the objectives of implementing a circular economy include: reducing energy consumption and the use of green energy, reducing greenhouse gas emissions and waste, as well as avoiding the depletion and degradation of natural resources;
- resilience – this is a feature of industrial production that has a high degree of reliability. Such production is resistant to disruptions during a crisis resulting from the company's operation in the technological, economic and geopolitical environment.

The topic of Industry 5.0, although it is only a certain concept, has so far published a large number of literature on it. The goal related to the implementation of the Industry 5.0 philosophy focusing on people is the subject of interest, among others (Pizoń et al., 2023a, 2023b; Brunetti et al., 2022). Pizoń et al. (2023b) draws attention to the challenges that should be faced by organizations that intend to implement the considered concept. These include (Pizoń et al., 2023b):

- social challenges,
- technical challenges,
- security challenges,
- legal and ethical challenges.

The human-technical relationship should be a consequence of human needs and the type of available technology (Pizoń et al., 2023a). Hence, (Brunetti et al., 2022) was interested in various intelligent technical means, considered from the point of view of designing human – machine systems operating in an industrial environment. The work carried out in this area was reviewed to highlight the advantages and disadvantages of each described technology and its application in the described area. Additionally, guidelines resulting from the human – centric approach were adopted for the integration of intelligent technologies in an Industry 5.0 enterprise.

The publication (Adel, 2022) draws attention to the need for proper communication between machines and their operators when the goal is to implement the 5.0 concept in companies. This can be guaranteed by implementing solutions developed in knowledge fields such as robotics and artificial intelligence (Adel, 2022). This allows for e.g. training using virtual or augmented reality techniques in employee training, which does not require stopping the production line, which contributes to reducing the company's operating costs.

In (Nahavandi, 2019) it is expressed that the fifth revolution will see the light of day when its three main elements – intelligent devices, intelligent systems and intelligent automation are fully connected with the physical world in cooperation with human intelligence.

Due to the challenge of Industry 5.0, there is a need to guarantee sustainable development. This is a concept that is increasingly being implemented as a management tool in enterprises. Its aim is to combine the economic needs of the company with the ecological needs of the natural environment, as well as the social needs of people living in a selected country or on a given continent (https://www.kone.pl/informacje-referencje/wiadomosci/zrownowatyny-rozwoj-a-spoleczna-odpowiedzialnosc.aspx). The definition of sustainable development speaks of a process of change in which the use of resources, the direction of investments, shaping technological development and institutional changes of the company and the state are compatible and mutually reinforcing in order to meet the needs of current and future generations. (https://www.kone.pl/informacje-referencje/wiadomosci/zrownowatyny-rozwoj-a-spoleczna-odpowiedzialnosc.aspx). Environmental sustainability is the ability to maintain ecological balance in our planet's natural environment and protect natural resources to support the well-being of current and future generations. The concept of economic sustainable development is related to economic development and is a process in which the exploitation of natural resources, the direction of investment, the direction of technological development and institutional changes or reforms are coordinated and harmonious and increase both the current and future potential to meet human needs (https://www.elibrary.imf.org/display/book/9781557755421/ch010.xml).

Social sustainable development, presented (Ciarko, Paluch-Dybek, 2014; Murphy, 2012; Morck, Yeung, 2009) focuses on concern for the social development potential accompanying economic growth.

Sustainable development covers the human population, the world of animals and plants, ecosystems, the Earth's natural resources, energy resources, and also treats in an integrated way the most important challenges facing the world, i.e.: fighting poverty, gender equality, human rights and his security, education, health, intercultural dialogue (Ciarko, Paluch-Dybek, 2014).

A quantitative approach to sustainable development is presented in (Strezov, 2017).

The issue of sustainable development as a key goal of the Industry 5.0 concept is addressed in (Baig, Yadegaridehkordi, 2024). These literature items discuss the current status in the area of Industry 5.0 technologies (which are the Internet of Things, artificial intelligence (intelligent stationary and portable devices) and collaborative robots/cyber-physical systems, but also big data, digital twins, machine learning) for needs to ensure sustainable development (Jafari et al., 2022; Maddikunta et al., 2022).

Resilience, the ability to respond to disruptive changes such as trade wars, pandemics and climate impacts, has become an essential element of running a business. Industry 5.0 technologies play an important role in developing industry agility and resilience through data collection, automated risk analysis and improved security. The issue of resilience as a problem of the Industry 5.0 economy is addressed by (Leng, 2023; Romero, Stahre, 2021; Kaasinen, 2022).

In parallel, with the concept of Industry 5.0, the idea of Society 5.0 appeared – a modern, future-oriented and human-centered society in which the integration of cyberspace and the real world will take place using the latest technologies such as artificial intelligence, the Internet of Things, robotics and big data. Society 5.0 is a super – intelligent society that aims to create a world where essential goods and services are delivered to everyone at any time, anywhere, regardless of region, age, gender, language or other restrictions. Its goal is to simultaneously achieve economic growth and prosperity and overcome social challenges, thereby contributing to the well-being of the global community (du Vall, 2019). Particular attention was paid to this philosophy in (Fukuyama; Shiroishi et al., 2018, Wlazło, 2021; Grudowska, Ziel, 2022; Kiepas, 2020).

The comparison, complementation and co-evolution of the Industry 5.0 concept with the Society 5.0 concept is proposed in (Huang et al., 2022), in order to address the relevant fundamental arguments regarding Industry 5.0 and Society 5.0, which can be a fundamental inspiration for future research and discussion and can accelerate the development of Industry 5.0 and Society 5.0. The results of the comparison of Industry 5.0, Society 5.0 and Smart Cities and Villages are presented in (Kasinathan, 2022).

2.2. Maintenance in Industry 5.0 enterprise – bibliography research

Implementation of the Industry 5.0 concept in enterprises requires consideration of the possibilities of its implementation in individual areas of its activity. One of them is the operation and maintenance of technical means involved in the production of a product or the provision of services. Its aim is to maintain and restore the operational suitability (of machines, devices, buildings). Contemporary problems requiring solutions in this area include (https://utrzymanieruchu.pl/zrownowazone-utrzymanie-ruchu-jak-systemy-cmms-przyczyniaja-sie-do-osiagniecia-celow-zrownowazonego-rozwoju/):

- increasing operating costs and increasing competition; they force enterprise management to look for effective strategies and operational policies that will ensure the stability of enterprise operations as well as minimizing the negative impact of the use of technical means on the natural environment,
- lack of awareness regarding the life cycle of devices; it may lead to excessive consumption of maintenance resources, generation of waste and frequent and expensive repairs,
- the need to reduce the negative impact of overloading employees with work on their motivation to work and to optimize the use of resources – media due to rising prices,
- occurrence of accidents and machine failures, which not only pose a threat to employees, but also generate costs related to downtime and loss of customer trust.

The answer to the above – mentioned problems may be activities in the field of maintenance management of technical means, which may include pro – environmental strategies. Their examples are Green Maintenance and Sustainable Development. Green Maintenance Strategy according to (Jasiulewicz-Kaczmarek, 2019) is a set of all technical, administrative and management tasks during the life cycle of a technical means, aimed at maintaining or restoring it to a state in which it can perform the required function in an environmentally friendly manner. The implementation of the Green Maintenance policy will be influenced, among others, by the strategy of using technical resources, the method of planning maintenance works, as well as the repair technologies and materials used (Jasiulewicz-Kaczmarek et al., 2023).

The purpose of implementing the sustainable development strategy in maintenance, according to (Jasiulewicz-Kaczmarek, 2023) is also achieving certain social benefits (ensuring a proper working environment, health and safety of employees and their satisfaction) in addition to achieving environmental benefits (technical means should be operated and maintained in a rational manner, taking into account the rational use of natural resources and reducing the impact on the natural environment (electricity consumption, emissions , waste)).

By (Marco Baur et al., 2020) an appropriate maintenance strategy/policy can extend the life of a technical asset and prevent unexpected failures that may affect losses in production activities, schedule irregularities and lower product quality, being key to reducing costs and improving productivity.

The topics of other aspects of the Industry 5.0 economy (human-centricity, resilience) in operation and maintenance management are represented by selected publications, including: (Siew et al., 2020, 2021; Almeida et al., 2023; Kohl et al., 2024; Sun et al., 2022; Bukowski, Werbińska-Wojciechowska, 2020).

3. The concept of computer maintenance management systems in an Industry 5.0 enterprise

The above – mentioned problems experienced by enterprises and the suggested ways to cure them require attention to the means that are necessary to achieve the maintenance goals consistent with the Industry 5.0 concept. The chosen mean is a CMMS system that supports tasks related to the operation and maintenance of technical objects. CMMS systems are successfully and increasingly used in many organizations. Currently, they are adopted for use in enterprises in accordance with the Industry 4.0 concept. In this case their usefulness was demonstrated in (Wieczorek, 2023). Since the Industry 5.0 concept complements the Industry 4.0 concept, it can be assumed that a CMMS system will also be used within it. The application of the Industry 5.0 concept and CMMS system in it must involve the analysis of basic aspects of maintenance management, i.e.:

- maintenance strategy,
- structures – organizational, information and decision – making,
- activities,
- culture.

Compliance with the assumptions of the Industry 5.0 economy will be possible if the CMMS system is treated as:

- eco – innovation,
- “provider” of well – being,
- guarantor of resistance.

3.1. CMMS class system as an eco-innovation

There are many definitions of eco-innovation. One of them, based on the definition proposed by René Kemp and Peater Pearson (Daktyw, Rybaczewska-Błażejowska, 2020) says that eco – innovation includes the production, exploitation (operation and maintenance) or application of a product, service, production process, organizational structure or management method that is new for the organization or users/operators, and at the same time ensuring, reducing the risk of negative impact on the environment, pollutant emissions and other effects related to the exploitation of natural resources from a life cycle perspective. However, according to (Daktyw, Rybaczewska-Błażejowska, 2020) eco-innovation means developing products and processes that contribute to sustainable development and using this knowledge to achieve direct or indirect environmental benefits in the enterprise and in its business environment .

Therefore, a CMMS system will be an eco – innovation if it supports the planning and implementation of tasks in accordance with the Green Maintenance and Sustainable Development policies. For this purpose, an analysis of the above-mentioned aspects of maintenance management should be carried out, including procedures implemented in organizations, as well as information systems that will function as a result of their implementation. The procedure enabling such an analysis is presented in (Wieczorek, 1999). However, its use must be preceded by the development of a model that will be used at one of the stages of the above – mentioned method. This could be a DFD (Data Flow Diagram) model that could be developed to meet the needs discussed. An example of such a diagram, applicable in the case of ongoing repairs of a public transport bus, is shown in Fig. 1.

Analysis of the information system in accordance with the model presented above will allow for:

- indication of the optimal information system, taking into account the assumptions of sustainable development, in which a CMMS system is implemented,
- indication of the optimal form of the CMMS system itself, which will allow achieving the intended goals of the adopted operational strategy/policy,
- election of computer tools that will be integrated with the CMMS system.

Not all data and information are collected, transferred and processed in the CMMS system, in accordance with the Sustainable Development policy; this can be stated on the basis of (Loska, 2002). Therefore, they were not included in the proposed model, so it would be necessary to:

- supplement the activities in the process/system (included in the model) with those that are consistent with the sustainable development strategy (the completed activities and transitions with data are shown in Figure 1 using dashed lines),
- meet the need to integrate CMMS with other systems.

The complex nature of processes and systems, shown during the analysis of the information system of the maintenance organization and given to them by the need for sustainable development, may require the integration of CMMS systems with other systems that will enable:

- simulation using a digital twin to estimate the values of measures/indicators for assessing production and maintenance efficiency,
- decision making support – in this area, e.g. expert systems can be used to plan and implement maintenance and repair tasks.

As a component of an integrated IT system including these tools the task of the CMMS class system will be:

- provide data for analyzes conducted using the RCM (Reliability Centered Maintenance) method, FMEA (Failure Mode Effect Analysis, analysis of environmental effects), another ones and use the obtained data in making decisions about the selection of tasks (based on 6R),
- visualization (in the form of a report/system report) of decisions that need to be made in accordance with the concept of Sustainable Development.

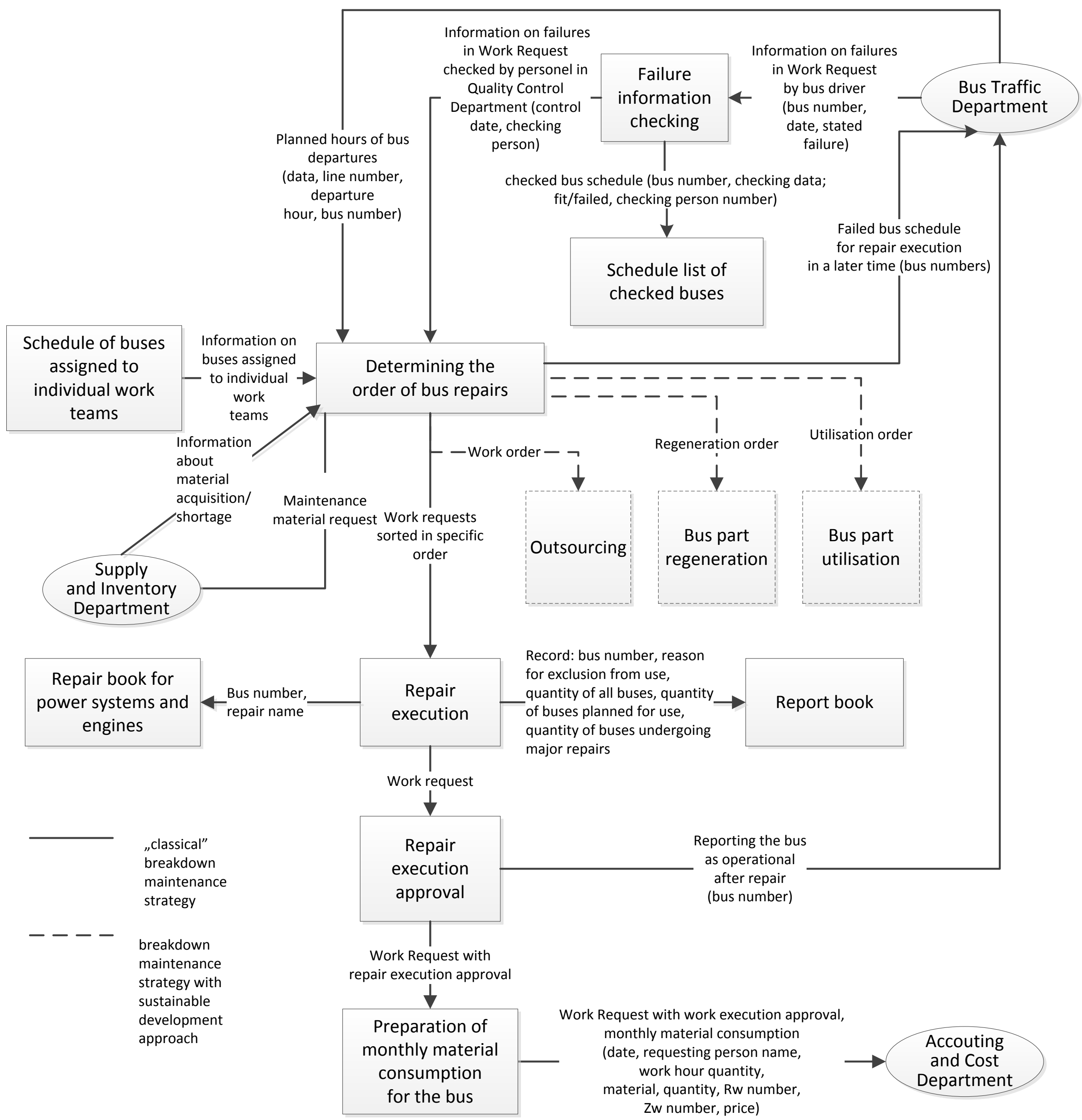

Figure 1. Data Flow Diagram (DFD) for the procedure of city – bus ongoing repairs.

3.2. CMMS class system as a "provider" of well-being

Implementing the sustainable development policy also means meeting social needs. The social dimension of sustainable maintenance concerns the following needs (Jasiulewicz-Kaczmarek et al., 2023):

- employee safety and health,
- working hours (compliance with legal requirements),
- financial resources allocated to employee training and investments in new hardware and software supporting employees in their work.

An important problem, the importance of which will become more and more meaningful in the future, is the aging of societies and the related increasing share of work carried out by such people in the enterprise. A CMMS system will be a "provider" of human well-being: an employee of an enterprise, if its management is proper, including taking into account the employee's age. This means that there is a need to properly plan, organize, motivate and control work for employees to be performed in appropriate locations, depending on working conditions. Tasks in this area include:

- reducing the frequency of employee work in locations where working conditions are the least favorable for them and/or redesigning the workplace,
- organization of work so that the routes used by employees are suitable for employees of different ages,
- organization of maintenance and repair works so that employees can complete their tasks on time, while ensuring high quality of their work,
- training that will enable the use of modern technologies, including those supporting the protection of the natural environment (so – called "green" competences).

Achieving the goal of reducing the frequency of employee work in selected locations will be possible thanks to the integration of methodological and tool solutions based on the model: human – technical means – environment. It is shown in Fig. 2. The environment in this case will have different impacts: positive and negative on humans. Its development is an example of a model solving the problem of work frequency, described in (Groja, 2014; Wieczorek, 2018). This model concerns the adaptation of the production line in an enterprise in the automotive industry; in the opinion of the author of the article, such a model can also be used for the organization of maintenance and repair works. The method developed based on this model involves assigning employees to tasks taking into account the ergonomics criterion. Its use will require the use of computer ergonomic analysis tools, an example of which is the 3DSSPP system.

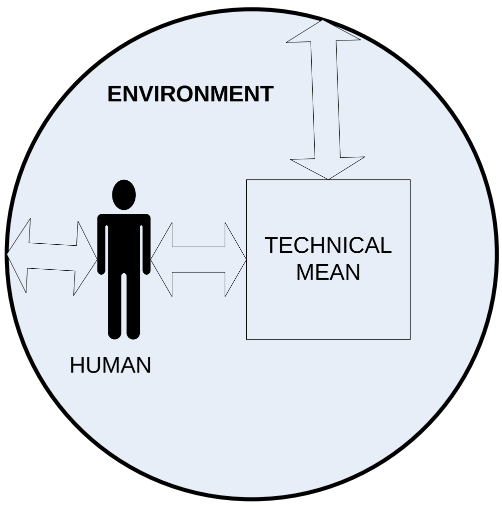

Figure 2. Man – technical mean – environment model system.

Achieving the above – 2nd and 3rd mentioned objectives will consist in the use of vision systems: monitoring cameras, which will be able to detect potential threats to the health and life of employees and respond to them in real time (Gacmęga, 2024). Moreover, vision systems should be used to monitor environmental conditions, such as temperature, humidity or the presence of harmful substances, which allows maintaining appropriate safety standards (Gacmęga, 2024). Data on the above-mentioned environmental conditions, including inconveniences and threats affecting the work of employees, should be processed and visualized using a GIS (Geographic Information System), and on their basis and using a CMMS system, employees can be assigned to work in appropriate locations.

The fourth goal, which is employee training, can be achieved using computer systems supporting knowledge management. In an aging society, the knowledge of older people differs from that of younger people in enterprises. Therefore, it is necessary to acquire and share knowledge, which is why systems of this class should have various knowledge repositories implemented, which should be supplemented with knowledge derived from the use of the mentoring method in order to acquire knowledge by employees (examples of such repositories are shown in (Wieczorek et al., 2012). In such cases, the CMMS system will provide data and information about:

- technical means,
- operational and maintenance events,
- operational and maintenance processes,
- systems for the operation and maintenance of technical means and systems that support them,
- employees – machine operators and maintenance staff.

The concept of well – being is increasingly associated with the concept of positive thinking, which is a consequence of the presence of the field of knowledge in scientific research, which is positive psychology or the psychology of emotions. It is expected that they will contribute to the development of man - technical means – environment, which will be implemented in solutions using CMMS systems.

3.3. CMMS class system as a guarantor of resilience

The concept of Industry 5.0 is related to the concept of resilience, including technological resilience. It can be guaranteed through an appropriate technical or technical – social assessment of the technical means and/or the system: man – technical means – environment, carried out using the spatial econometrics method or accelerated aging models, or by improving the reliability of technical means, in particular through the use of appropriate operational reserves, but also by implementing more perfect technical diagnostics and predictive maintenance methods, based on classic prognostic models, but also efficiency and ergonomics assessment models supporting diagnosticians and forecasters who are elderly people, which include:

- anthropometric methods, the use of which, together with the use of artificial intelligence (rule method) and a cobot compensating for human disabilities, will allow for the performance of diagnostic work, taking into account the physical dysfunctions of older people,
- cognitive methods, the use of which, together with the use of artificial intelligence (rule-based method), will allow for the assessment of the technical condition of the technical means, taking into account the dysfunctions that will appear in the thinking of the human diagnostician of the technical means.

In the discussed case, the CMMS class system, for the purposes of making decisions about the implementation of maintenance and repairs, should provide data on the technical means in use, including data on their technical condition.

4. Conclusions

The future is the Society 5.0 philosophy, which will be visible in all spheres of human life, including the work environment. It is closely related to the concept of Industry 5.0, the competitiveness of which in the conditions of a market economy will require new methodological and tool solutions that will be integrated with each other. These solutions include CMMS systems, which will guarantee the correct human – technical relationship, sustainable development, and ensure technical, economic and environmental resilience in the organization. Sustainable development is concern for human problems in the work environment. A social problem is the aging of the society, which will contribute to an increase in the number of older people in relation to all company employees. This will make it necessary to support the work of such people with complex technical systems in which models of the human-technical means-environment system will be implemented, taking into account not only the proper functioning of humans, but also their dysfunctions. CMMS systems should also be an element of such systems, which will enable the sharing of data and information not only about the machine, but also about people. This topic will be the subject of further research.

Acknowledgements

This article is the result of research conducted at the Department of Production Engineering, Faculty of Organization and Management, Silesian University of Technology titled: Zastosowanie nowoczesnych metod i narzędzi do badania zagadnień związanych z Priorytetowymi Obszarami Badawczymi Politechniki Śląskiej. Research work no.: BK-266/ROZ3/2024 (13/030/BK_24/0083).

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