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ASSESSMENT OF USEFULNESS OF CMMS CLASS SYSTEM FOR INDUSTRY 4.0 ENTERPRISE

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Purpose: The purpose of the article is recognition of the possibility of using CMMS class systems in supporting maintenance in the conditions of the implementation of the Industry 4.0 concept.
Design/methodology/approach: The above-mentioned purpose was achieved as well by examining the opinions of employees of the selected company as the mathematical formula for CMMS social assessment.
Findings: During the conducted research, it was found that there is a need to use CMMS class systems as a tool in the area of maintenance in an Industry 4.0 enterprise. It can be deduced from the ratings given by the employees of the researched company to these systems. There is also a need for further research and development of this topic as well as for providing appropriate training and support for employees for effective using CMMS class systems.
Research limitations/implications: The article shows the method of social evaluation of a technical solution which is a CMMS class system. Such a system may be implemented if the results of such an assessment are verified on the basis of data on maintenance activities of a technical, economic, organizational or environmental nature. Therefore, it is justified to continue research in the mentioned area using indicators and measures of the maintenance effectiveness (KPI, OEE, measures/indicators of reliability of machines, devices and systems), as well as methods and techniques of their simulation and forecasting in the discussed area.
Practical implications: The indicator for social evaluation can be used at the stage of selection, purchase of a CMMS class system of a production or service company or when carrying out comprehensive or partial changes in its information structure, ending with the implementation of a selected system of this class.
Social implications: Conducting a research using the method proposed in the article among the company's employees may convince them that the introduced changes are justified and beneficial for themselves, the company and its environment.
Originality/value: The article has a cognitive and application value, because it proposes the use of the original set of questions contained in the survey, as well as the original evaluation indicator of the CMMS class system.

Keywords: exploitation, maintenance, management, CMMS, Industry 4.0.

Category of the paper: research paper.

1. Introduction

The need for enterprises to compete in the conditions of a market economy forces them to take actions that allow them to achieve their intended goals. One of them is the implementation of the Industry 4.0 concept, which assumes the use of the Internet of Things and intelligent systems used in the acquisition, transmission and processing of large amounts of data, in particular for the purposes of controlling machines, including robots. One of the areas of the company's activity requiring the use of such data is the operation and maintenance of technical means. The occurrence of complex algorithms that require the collection and processing of such data requires the possession of an appropriate computer-aided tool, which in the discussed area can be a CMMS class system (Computer Maintenance Management system) (Walczak, 2012; Palka, Ciukaj, 2019).

James Harrington, an English writer, publicist and philosopher once said that "no company has the time or resources necessary to learn only from its mistakes". Therefore an implementation of such systems must be making thoughtful decisions, including conducting their analyses, that will make it possible to determine their usefulness for a company functionning, among others, in the conditions of industry 4.0. Such analyzes should include technical, economic and environmental aspects, as well as social aspects of maintenance, which are a novelty described in the literature.

Therefore, the article reviews the literature on the means and ways to support the implementation of the concept of industry 4.0, including CMMS class systems. Particular attention was paid to the social evaluation of technology (Technology Assessment) as a way to support decision-making on the implementation of tools of the discussed class. An original method of social evaluation of technology was proposed, which is the CMMS class system, and then it was verified on the example of a selected enterprise (Kaźmierczak et al., 2015; Kaźmierczak, 2013).

2. Means and methods supporting the implementation of the concept of Industry 4.0

The improvement of the company's competitiveness becomes possible thanks to the increase in productivity, which can be achieved through the use of the digital revolution in enterprises. It will be carried out through the implementation and operation of measures and methods supporting the implementation of the concept of industry 4.0 (Palka, Rizaoglu, 2019). Some of the currently used means and methods of the Industry 4.0 concept in enterprises are described below.

The Internet of Things (IoT) and/or the Industrial Internet of Things (IIoT) – according to (Fidali, Rybka, 2021), (Atzori et al., 2010) is a network information technology of physical objects (sensors, machines, cars, buildings and other technical means), which enables the interaction and cooperation of these objects to achieve common goals. The technologies that, according to (Mukhopadhyay, 2014), will control the Internet of Things in the future include sensor techniques, including RFID, SmartThings technology, nanotechnology and miniaturization. The Internet will help transform businesses and societies into sustainable and secure ones that enable efficient interaction between the physical world and its digital counterpart, what is commonly referred to as a cyber-physical system. The Industrial Internet of Things, on the other hand, covers the domains of machine-to-machine (M2M) technology and industrial communication technologies with automation techniques. According to this literature, IIoT paves the way to a better understanding of the manufacturing process, thus enabling efficient and sustainable production.

Artificial Intelligence can be defined as a sub-discipline of computer science dealing with the implementation of data processing systems that perform functions characteristic of human intelligence, such as reasoning, learning and self-improvement. The use of artificial intelligence by machines to complete complex tasks, reduce costs and improve the quality of products and services is the basic principle of intelligent enterprises and Industry 4.0 enterprises (Bahrin et al., 2016).

Big data should be understood as data sets that are characterized by a large volume, significant speed with which new data is generated (velocity) and a large variety of formats, dimensionality, and structure of the data itself (variety). In maintenance, according to (Jamrozik, 2018), large amounts of data are collected in SCADA or CMMS systems (Razali et al., 2020; Wieczorek, 2019).

Modeling and simulation - currently, there is an urgent need to develop simulation models, because an increasing amount of data is currently being processed in enterprises, which is the result of the increase in the level of automation and robotization and the need to ensure high flexibility of modern manufacturing systems, using streams from interconnected subsystems (Krenczyk, Pawlewski, Plinta, 2022). Contemporary simulation models use the concept of a "digital twin", which should be understood as a virtual representation of the product as an integrated data system, models and analytical tools imposed on the entire product life cycle (Fidali et al., 2021). Examples of the use of simulation methods and techniques in the operation and maintenance of technical systems in the conditions of Industry 4.0 are shown in (Palka, 2021a, 2021b, 2021c; Paszkowski, Loska, 2018).

Machine learning, in the context of Industry 4.0, is one of its key elements. Machine learning is a field of artificial intelligence that enables computers to automatically learn from available data and make decisions or perform tasks without having to program in an explicitly defined way. This technology is used in various industrial areas, such as production, logistics, data analysis and quality management. Thanks to its ability to analyze huge data sets, machine

learning allows you to extract hidden patterns, discover dependencies and predict future events. In the context of CMMS-class systems, machine learning can be used to create predictive models that make it possible to predict failures and necessary maintenance. By analyzing historical maintenance data, machines can "learn" to recognize patterns that indicate impending problems or failures. This allows you to schedule maintenance more efficiently, minimizing production downtime and emergency repair costs. Machine learning is also used in the optimization of production processes. By analyzing data on machine performance, production quality, consumption of raw materials or environmental parameters, CMMS class systems can provide recommendations for process optimization, identifying factors affecting problems or reducing losses.

Cloud computing is the storage and processing of data on remote servers that are accessible via the Internet. Cloud computing offers many benefits for enterprises, especially in the context of the large amounts of data generated as part of Industry 4.0. Cloud computing enables flexible scaling of resources, which is particularly important when processing large amounts of data. Enterprises can adapt their computing resources to current needs, which allows for efficient data processing without the need to invest in their own infrastructure. Cloud computing ensures the availability of data and applications from any place and device connected to the Internet. Employees can freely use data and applications, regardless of location, which promotes a flexible and mobile work environment. Cloud computing can provide a higher level of data security than traditional in-house solutions. Cloud services often offer advanced security mechanisms, such as data encryption, access controlled by authorization and authentication, as well as regular backups. The use of cloud computing allows enterprises to avoid high costs related to the purchase, maintenance and updating of their own infrastructure. Cloud service charges are typically flexible and scale based on actual resource usage. Cloud computing enables easy integration of various systems and applications. Enterprises can create integrated environments where data and applications are linked and exchange information. Cooperation between various departments of the company is facilitated, which promotes synergy and efficiency of activities (Palka, Ciukaj, 2019).

The Integration of IT Systems is another important aspect supporting the implementation of the Industry 4.0 concept. It consists in connecting various IT systems in the company in a way that enables a smooth flow of data and information between them. This technology allows for uniform data management in the enterprise. Information collected in various systems is synchronized and up-to-date, which enables informed decisions to be made based on complete and consistent knowledge. The integration of IT systems eliminates the need to manually transfer information between different areas of activity. Data is automatically transferred between systems, which shortens the response time and minimizes the risk of errors resulting from manual data entry. Consolidated collection of data from various areas of the company enables advanced data analysis, pattern detection, trend identification and strategic decision-making based on reliable information (Loska, 2012, 2015; Winkler et al., 2012).

Virtual Reality (VR) is one of the tools that can support and facilitate the implementation of CMMS class systems in an Industry 4.0 enterprise. Thanks to VR, it is possible to create realistic visualizations of production processes, simulations of machine operation and training for employees. By interacting in a virtual environment, employees can gain practical experience and improve their skills in the use of CMMS class systems. In addition, VR enables remote training and real-time collaboration, which is of great importance in the context of global employee teams. Employees can meet in a virtual environment using advanced VR features such as virtual tools and guidance. This contributes to the effective transfer of knowledge and increasing the effectiveness of the implementation of CMMS class systems in an Industry 4.0 enterprise. Virtual reality combined with CMMS class systems also allows for real-time data monitoring and analysis. Thanks to VR, it is possible to visualize performance indicators, the condition of machines or production processes, which makes it easier to identify areas that require improvement. This enables the company to make quick decisions and optimization activities based on real data collected by CMMS class systems.

3. Literature research on the application of computer aided maintenance in the mentioned area

Conducting exploitation of technical means in the conditions of Industry 4.0 is possible if management in this area is carried out properly. One of the guarantors of the correct implementation of the function of managing the operation and maintenance of technical means (planning, organizing, motivating and controlling) is the collection, processing, transfer or sharing of data, information and/or knowledge using the CMMS class system. This knowledge may include data/information:

- on measures and technical systems,
- on operational events (intended and unintentional),
- on operational processes,
- about a person - users and technical means.

In many Research Centers, including the Department of Production Engineering of the Silesian University of Technology, research has been carried out for many years on the use of the CMMS class system in the operation and maintenance of technical means. Their results are books, articles, master's and doctoral theses, reports on research work carried out - internal (statutory) and work for the industry: (Kaźmierczak, 2000; Legutko, 2007; Orłowski, Lipski, Loska, 2012; Loska, 2012, 2015, 2016; Loska, Paszkowski, 2017; Palka, Ciukaj, 2019; Wieczorek, 2019; Wieczorek, Rozmus, 2017; Wieczorek, Szulc, Karwot, 2011). So far, they have focused on the following areas:

- application of the CMMS class system in the planning and implementation of maintenance and repair works,
- the use of CMMS class systems in the control of activities in the field of operation and maintenance of technical means,
- cooperation of CMMS class systems with systems of other classes (tools supporting decision making, simulation tools, tools supporting reliability analyses, systems supporting RCM analyses, geographic information systems, virtual reality systems),
- modeling of objects/locations in CMMS class systems,
- implementation of CMMS class systems.

These works are continued due to the need to implement the industry 4.0 philosophy in organizations and the need to use CMMS class systems in the conditions of its implementation. The subject of the relationship between the implementation of the Industry 4.0 concept and the subject of CMMS class systems has been presented in, among others, the following publications: (Azra, Dachyar, 2020; Cao et al., 2012; Razali et al., 2020; Nordal, El-Thalji, 2021; Dalzochio et al., 2020). Under the conditions of the implementation of the Industry 4.0 philosophy, by obtaining data/information from machines from the Internet of Things to CMMS class systems, transferring data from them to databases of other supporting systems (e.g. MRP, ERP, computer aided simulation system, etc.), or providing different users, it is possible to conduct a properly adopted policy of exploitation of technical means. Therefore, it becomes necessary to evaluate the CMMS class system at the stage of its implementation or to analyze the information system in order to carry out their modification. This assessment must take into account the needs arising from the operation of machines and devices in the conditions of industry 4.0. These needs include, among others (Jamrozik, 2018):

- detection of failures and faults by the machine in which they occur,
- planning tasks in the field of preventive and predictive maintenance, where the plans will be adapted to current data from various areas of the company's activity,
- automatic generation of reports containing data from various areas of the company's activity,
- conducting inspections of machines and devices based on solutions in the field of automation and robotics,
- implementation based on solutions in the field of automation and robotics of transactions in warehouses of material resources used in the implementation of tasks in the field of servicing technical means (spare parts, consumables and consumables, machines and service devices),
- optimization as an antidote to the failure to use data from CMMS class systems and systems derived from them.

One of the problems in the implementation of CMMS class systems, as well as other solutions in the field of the Industry 4.0 concept, is their evaluation. In connection with the subject of research on the use of CMMS class systems in the enterprise, in the opinion of the author of the article, it is important to carry them out in the following research areas:

- development of a method of comprehensive assessment of maintenance solutions supporting the implementation of the Industry 4.0 concept in the enterprise. This assessment should cover the technical, economic, environmental and social aspects of these solutions,
- development of methods and techniques for obtaining, collecting and processing data, information and knowledge for the purpose of conducting the above-mentioned assessment. The use of not only CMMS class systems, but also expert systems should be considered in this area.

An element of a comprehensive assessment of the solutions described in the article should be a social assessment. This assessment allows you to receive subjective information, which is the opinions of users about the technical means they use. The reason for their implementation should be the risk of side effects and consequences that are difficult to predict (Stankiewicz, 2010), which also applies to CMMS class systems used in the implementation of the Industry 4.0 concept. In the literature, this way of approaching a technical measure is referred to as Technology Assessment. This area of research is constantly evolving. Examples of publications on Technology Assessment include: (Kaźmierczak, 2013; Kaźmierczak et al., 2015; Grunwald, 2019).

One of the significant problems of the social evaluation of technology are the gaps in the availability of methods and/or their use for the purposes of implementing selected types of technologies. Examples of such solutions are CMMS systems. Their application for the purpose of Industry 4.0 conception require an assessment of the influence of exploited technical object, operation and maintenance events, processes and systems to the company and its environment. Many attempts to deal with this problem have been made, whose example is (Michalski, 2011). Therefore, the task of developing a method to support the assessment of CMMS class systems as tools for implementing the concept of industry 4.0 was undertaken in the article.

4. The concept of a method for social assessment of the suitability of CMMS class systems in an Industry 4.0 enterprise

The concept of the method of social assessment of the suitability of CMMS class systems in an Industry 4.0 enterprise is based on considering the social and human perspective in the process of evaluating these systems. This helps to understand what the social, organizational,

and psychological factors are affecting the effective implementation and use of CMMS systems in the context of Industry 4.0. The main concept methods are shown in Fig. 1.

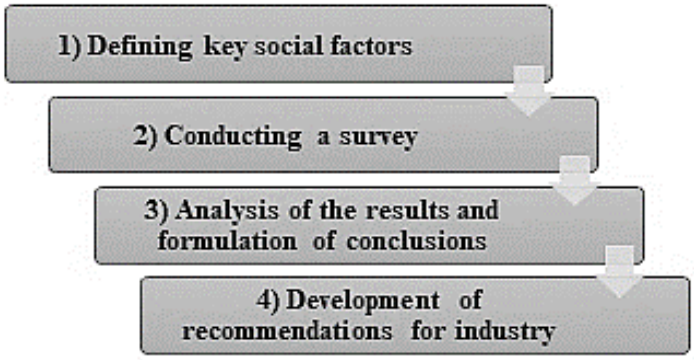

Figure 1. The main concept methods.

Source: own study.

The method of social assessment of CMMS class systems in an Industry 4.0 enterprise consists in identifying key social factors that affect the effectiveness of the implementation and use of these systems. The survey focuses on company employees who are in contact with CMMS systems. The questions concern employees' perceptions, expectations, concerns, benefits and suggestions related to CMMS systems. The analysis of the results allows to identify dominant patterns and trends in the social assessment of CMMS systems, and the conclusions can help in understanding the key social factors for the effectiveness of the implementation and use of these systems. Based on the analysis, recommendations can be developed to improve the implementation of CMMS systems, such as employee training, information campaigns, emotional support, organizational changes or user interface customization. The implementation of these recommendations is aimed at increasing the acceptance, involvement and effectiveness of CMMS systems in the enterprise.

4.1. Survey study

Implementation of a CMMS class system may be a chance to meet the needs of the company's management resulting from the implementation of the Industry 4.0 concept. It can be carried out using the assessment of their suitability in the enterprise for the purposes of implementing this concept. An element of this method is a survey in which the following questions appear:

1. To what extent, in your opinion, would a CMMS class system allow for the collection of a large amount of appropriate data (Big Data) and enable their processing in order to make rational decisions in the field of maintenance?
2. To what extent, in your opinion, would a CMMS class system with learning machines be able to improve the detection of failures and faults in the company where you work?

3. To what extent, in your opinion, would the CMMS class system with the Internet of Things (providing communication between machines and machines and the user) in the company where you work contribute to reducing the number and value of downtimes of machines and devices?
4. To what extent, in your opinion, would reporting using the CMMS class system as an element of an integrated automated system supporting the exchange of information between machines and between machines and people in the company where you work bring measurable economic benefits in the area of machine maintenance?
5. To what extent, in your opinion, would reporting using the CMMS class system as an element of an integrated automated system supporting the exchange of information between machines and between machines and people in the company where you work bring measurable economic benefits in the area of warehouse management (by implementing solutions in the field of the Industry 4.0 concept, including the concept of a smart warehouse?
6. To what extent, in your opinion, a CMMS class system with a relational database (optionally together with other supporting systems) and methods and techniques of computer simulation and short-term forecasting and artificial intelligence could in the enterprise where you Do you work effectively to support decision-making in the conditions of the philosophy of preventive and predictive maintenance, as well as the implementation of the green maintenance concept ?
7. To what extent, in your opinion, would the CMMS class system in the conditions of industry 4.0 in the company where you work contribute to improving the efficiency of planning and scheduling maintenance work, which would affect the implementation of production/service tasks according to plan?

The research sample consisted of 75 respondents representing various departments of the company of clothing industry, such as production, logistics and maintenance (it was assumed that selected persons know the processes and systems (including information and computer systems) in a company). Respondents were randomly selected (simple random sampling) from different working teams. Different hierarchical levels and work experience were included in the sample to obtain a variety of perspectives. The survey was voluntary and respondents were guaranteed confidentiality. With the help of a diverse sample, it is possible to obtain representative and comprehensive results regarding the social assessment of the suitability of CMMS class systems in Industry 4.0.

Each question was rated on a scale from 1 to 5, where 1 was the lowest score and 5 was the highest score.

Data from the surveys were the basis for calculating the value of the social evaluation index, calculated according to the formula:

$$W_i = \sum_{j=0}^{n} \left(P_{ij} \cdot K_{ij} \right) \tag{1}$$

where:

P – probability of occurrence of i – this answer (on i – this question in the survey) for j – this assessment,

K – this rating (from 1-5, where 1 - the lowest rating of i - this answer, 5 - the highest rating of i - this answer).

Probability of occurrence of i – this answer (on i – this question in the survey) for j – this assessment can be computed with the use of the following formula:

$$P_{ij} = \frac{n_{ij}}{N} \tag{2}$$

where:

n_{ij} – amount of persons filling the questionnaire, answering i – this question in the survey j – this assessment,

N – amount of all persons answering the questions in the all surveys.

The results of the survey were collected in a spreadsheet and analyzed. On this basis, the probability of a given answer and the social evaluation were calculated based on the formula (1). The conducted analysis is summarized in Table 1.

Table 1.
Results of the survey

N	Response scale					Social evaluation
	1	2	3	4	5	
1	0	5	7	29	34	
P	0,00	0,07	0,09	0,39	0,45	2,68
2	5	7	14	28	21	
P	0,07	0,09	0,19	0,37	0,28	2,21
3	0	2	11	37	25	
P	0,00	0,03	0,15	0,49	0,33	2,16
4	0	1	8	27	39	
P	0,00	0,01	0,11	0,36	0,52	2,95
5	1	0	8	15	51	
P	0,01	0,00	0,11	0,20	0,68	3,73
6	2	9	20	21	23	
P	0,03	0,12	0,27	0,28	0,31	2,60
7	0	0	3	27	45	
P	0,00	0,00	0,04	0,36	0,60	3,12

N - question number, P – probability.

Source: own study

In order to illustrate the obtained results and to maintain the legibility of their visualization, a bar graph was prepared. The results of the social assessment of the suitability of CMMS class systems in an industry 4.0 enterprise are shown in Fig. 2.

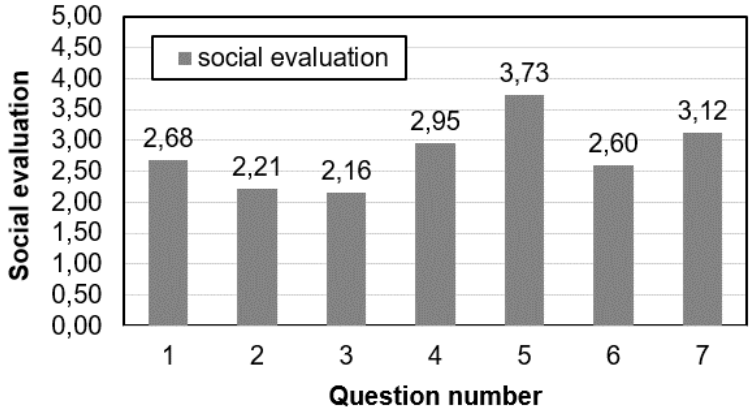

Figure 2. The main concept methods. The results of the social assessment of the suitability of CMMS class systems in an Industry 4.0 enterprise.

Source: own study.

The analysis of the answers to the questions shows that the overall assessment of the CMMS class system by the respondents is moderate, with slightly higher assessments of the economic benefits in warehouse management and maintenance planning. It is worth noting the lower ratings related to the possibility of collecting data, improving the detection of failures and faults, and reducing the number and downtime of machines and devices. These results may suggest areas where the CMMS system may require further development and improvement to better meet the expectations of respondents.

5. Summary and conclusions

This article aims to present a method for social assessment of the suitability of CMMS (Computer Maintenance Management System) class systems in the context of an Industry 4.0 enterprise. As part of the literature research and the conducted survey, an attempt was made to examine the opinions of employees from various departments regarding the potential benefits and use of the CMMS class system in their daily work.

As part of the survey, respondents were asked a number of questions regarding various aspects related to the CMMS class system. Employees were to assess to what extent they believe that the CMMS class system allows for the collection and processing of large amounts of data, improves the detection of failures and faults, reduces the number and value of machine downtimes, generates economic benefits and affects the effectiveness of planning maintenance works.

The analysis of the obtained results allowed the formulation of the following conclusions:

Question 1. Average rating: 2.68/5

The answers indicate that the respondents, on average, think that the CMMS class system has a moderate capacity to collect and process large amounts of data in order to make rational decisions in the field of maintenance.

Question 2. Average rating: 2.21/5

The answers suggest that the respondents attribute little value to the CMMS system in improving the detection of failures and faults in cooperation with the learning machines in their enterprise.

Question 3. Average rating: 2.16/5

The answers indicate that the respondents attribute low value to the CMMS system in reducing the number and downtime of machines and devices through integration with the Internet of Things.

Question 4. Average rating: 2.95

The answers suggest that the respondents attribute moderate economic values for reporting using the CMMS system as an element of an automated information exchange system between machines and humans.

Question 5. Average rating: 3.73/5

The answers indicate that the respondents attribute relatively high economic values for reporting using the CMMS system in the area of warehouse management, especially in the context of the concept of Industry 4.0 and the intelligent warehouse.

Question 6. Average rating: 2.60/5

The answers indicate that the respondents attribute a moderate value to the CMMS system equipped with a relational database, computer simulation methods, short-term forecasting and artificial intelligence in the context of supporting decisions regarding preventive and predictive maintenance and the implementation of the green maintenance concept.

Question 7. Average rating: 3.12/5

The answers suggest that the respondents attribute a moderate value to the CMMS system in improving the efficiency of planning and scheduling maintenance works and the implementation of production/service tasks as planned in the conditions of Industry 4.0.

The conclusions of the study confirm the great potential of CMMS class systems in Industry 4.0 enterprises. However, there is a need for further research and development of this subject, taking into account the specificity of individual industries and adapting solutions to specific requirements. It is also essential to provide appropriate training and support for employees to make the most of the opportunities offered by CMMS systems. The introduction of CMMS class systems together with learning machines, the Internet of things and other Industry 4.0 solutions can contribute to improving the detection of failures, reducing the downtime of machines and devices, increasing the efficiency of planning maintenance works and generating economic benefits. Implementation of these solutions, however, requires careful planning,

tailoring to the needs of a specific organization and ensuring the involvement of all stakeholders.

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