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MAINTENANCE DEVELOPMENT IN RELATION TO THE EVOLUTION OF CURRENT TECHNOLOGICAL PROCESSES

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Abstract: Technology has undergone several changes over time. The processes, products, as well as the equipment and machinery used have evolved. But these are not the only ones that need to evolve. Both the maintenance processes and the tools used, but also the maintenance procedures and stages must be constantly improved and keep up with the constantly evolving technology. Industry 4.0 changed the way in which all equipment and devices were used in production environments. A maintenance procedure used to perform maintenance work intended for analog equipment will not work on state-of-the-art digital equipment. In addition to the fact that the maintenance work will be carried out with difficulty, the equipment intended for this work will not have the optimal performance and the defects could remain unrepaired or, worse, their effects could worsen. The article aims to highlight the need to update maintenance plans in direct accordance with the evolution of technology. Thus, the paper presents the key elements that represent correlation factors between the technology used and the way of applying the current maintenance strategies.

Keywords: Industry 4.0, maintenance strategies, digitalization, technological progress, industrial technology innovation

1 RESEARCH CONTEXT

The permanent consideration of the evolution of the technological impact represents an important factor for the entire development process at the industrial level. Of course, with the significant industrial revolutions that led to change in general (Aghion & Tirole, 1994), multiple techniques, technologies and processing equipment were part of the integration in development plans implemented at the organizational level (Băjenescu, 1997). Taking into account both the market and the internal fields of manufacturing, maintenance and research, it can be deduced that the set of technologies from a certain period of time can

work with gaps or even with dysfunctions (Cañas et al., 2021) when it is applied to some systems or subsystems Updated. Thus, the research and development of process innovation fields contribute to the good functioning of the processing assembly (Chaib & Verzea, 2012). Any imbalance that occurs has repercussions in the future, with consequences at the level of results and the quality of the products or services provided (Chaib et al., 2014). For example, reorganizing and bringing the used assemblies to a modern level of use contributes to a better management of resources. These changes are made, as a rule (Chen et al., 2019), in the sense of the progress of the field in terms of the obtained performances. The consequences of a non-compliant quality are relevant (Fasulundeen et al., 2022): the waste of raw materials, materials and other resources, the inefficient use of machinery, the decrease in productivity and the increase in production costs (Ghobakhloo, 2020).

There is not something new that the industrial macro-system has evolved along with the great changes implemented by the fourth industrial revolution (Garg & Deshmukh, 2006). Among the main defining elements can be listed the drastic reduction of manufacturing costs, the development of the implementation processes of new methods (Kumar & Galar, 2018) and technologies such as the adoption of preventive maintenance plans and subsequently, those specific to digitization through applied prescriptive aspects (Lasi et al., 2014). Good management of resort equipment, technical resources and technological processes also represents a change in the directives of the management activity, oriented towards specific innovation activities. The problem of ensuring high reliability is, in general, the problem of integration into the design-exploitation process of activities (Munteanu & Bălănuță, 2009) such as the estimate of maintainability and the program for its planning, the analysis of the functional structures of the system, the determination of possible maintenance strategies and other necessary considerations (Murthy et al., 2002).

Depending on the way in which the application structures were organized, the specificity of the adopted solution can generate high performances based on the totality of the processing activities within the companies' integrated systems (Petrakis, 1995). The application of prescriptive maintenance plans in the context of computer-aided production management systems represents an area of interest for current doctoral research. In this way, analyzes will be carried out regarding the exploitation and application of modern systems on the general structure of the development of maintenance plans (Silvestri et al., 2020).

2 EVALUATION OF CURRENT MECHANISMS

The impact of technical progress on economic development is characterized by the functioning and the weight it has, along with accumulation, the development of new technologies. Investments appear, under these conditions, mainly as economic incorporations of technical progress, which involve the creation of new, perfected equipment (Ungureanu et al., 2016), the use of which increases the benefit of the technology itself. The mechanization of processes does not imply the release of the human factor from responsibilities, but, on the contrary, implies direct integration in the production of goods and services. In this way, through automation, we want to determine the conditions of development and process control. Moreover, through digitization, new concepts are introduced that induce the autonomous spirit within the good realization of production flows. The operation of the logical, reasoning conditions is a constitutive part of the entire decision-making process.

These stages must be understood as having appeared successively, according to the superior knowledge of the objective reality. In this way, automation becoming possible with the intensive improvement of mechanization stages, characteristic of the industrial revolution. The digitization and integration of the technologies specific to Artificial Intelligence has become possible through the lens of logical deductions made on high-performance equipment. The stages should not be understood as elimination, i.e. the beginning of one means the end of another, but they take place in parallel, thus facilitating the evolution of other techniques and methodologies.

Improving the quality of products in all economic branches, raising the technical level and perfecting manufacturing technologies is one of the priority concerns of economic activities at the current stage. At the same time, the improvement of the quality of products and services, based on the application of the results of scientific research, technological development and the introduction of innovative technical progress, is realized simultaneously with the increasingly efficient exploitation of the economic resources of industrial processes (Ungureanu et al., 2015).

Figure 1 illustrates the evolutionary structure of the systems applied to obtain maintenance plans. As a rule, the old technologies are interspersed even today in the maintenance processes ensured on the equipment. This is not necessarily an impediment in ensuring the availability of the systems as long as the operations performed are correctly applied and in accordance with the operating rules taken into account beforehand. However, considering that modern and high-performance devices are mainly used in today's society, it is necessary that the specific maintenance activities correspond to current needs. In this way, the possibility of wasting the time intended for maintenance operations with out-of-use and outdated techniques, which are no longer applicable to the systems used, is eliminated. Starting from corrective maintenance, where only the routine repairs carried out at the level of equipment were taken into account by replacing defective parts and using multi-purpose tools, we arrive at a more efficient method, such as prescriptive maintenance (Ungureanu et al., 2007). This provides for a much more detailed planning of all maintenance actions performed both at the level of the assemblies and at the level of the sub-assemblies of the system.

Thus, through the application of preventive methods, there is a reduction in the number and times of unavailability. Obtaining a modern system of maintenance activity is possible only by introducing and applying current techniques, which take into account the processes of automation and digitization of production flows and decision-making stages. By integrating prescriptive strategies, not only are defects identified much more efficiently, but we also want to obtain predictions regarding future defects. Digitization implies technological integration through the use of computational power.

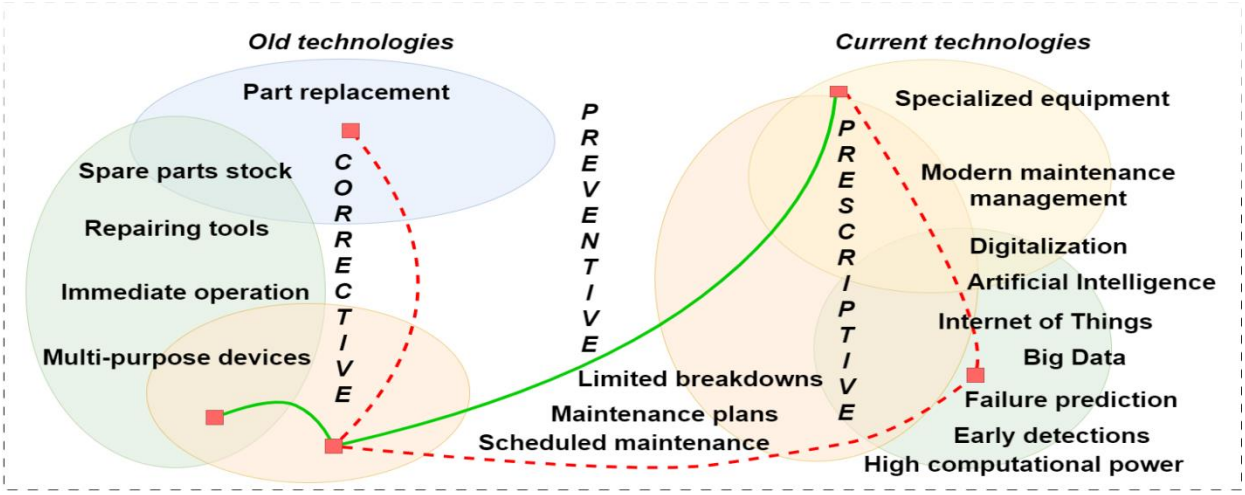

Figure 1. The structure of maintenance systems - theoretical approach regarding the evolution and development of methods

3 THE METHODOLOGY FOR APPLYING MAINTENANCE PLANS

The need to design a stable maintenance plan is a complex technique by which the specific maintenance processes are assigned a certain importance and a ranking according to the needs of the analyzed system. The identification of the weak parts of the system project contributes to the systematic approach to the management of subsequent inconsistencies that may intervene. In this case, the maintenance plans must also document the weighted importance of all defects identified in the past as well as those that are foreseen in the future (Ungureanu et al., 2015).

3.1 Maintenance procedures

In the design, development and use phases, the estimation of the maintenance methods used is a forecasting process that is based on the previous models, on the analysis of the causes and effects of the failures, on the evaluation of the parts and including the redundant testing. Both in the design stage and in the export stage, an essential role is represented by the quality and applicability of the stored data regarding the entire manufacturing process. Ensuring the necessary conditions for easy maintenance means ensuring accessibility for the less developed components. After each iteration of the validation process, it is recommended to specify the states of the success or failure stages in order to maintain a traceability of the results obtained. It goes without saying that applying theoretical analysis methods to the components of the system under maintenance is not enough (Ungureanu et al., 2010).

The practical, defining and procedural implementation is necessary for each stage of the development of the own maintenance plan for each individual system. If in the past the emphasis was not placed on the establishment of clear maintenance procedures, nowadays the need to establish clear conditions that will allow the concrete determination of the operations provided for the real operating conditions is noted. Specifying the physical and functional limits of each piece of equipment contributes to establishing normal operating conditions. The quality of the system, as a whole, depends on the introduction of automation and the quality

of the functioning of all the processes with which it interacts during use.

3.2 Application of specific concepts

As in any other optimization process of a current system or process, both the current technological functionalities and the architectural structure on the basis of which the system operates on a regular basis must be taken into account (Yan et al., 2017). The vast majority of parameters and update or optimization functions must be established starting from the relevant information found within the frequent use processes. If the new design does not start from the basic system, there is a possibility that the updated stages will not fully correspond to the maintenance needs. Consequently, the problems that could appear are to a large extent the result of the faulty integration of the components leading to integrative problems of the entire system.

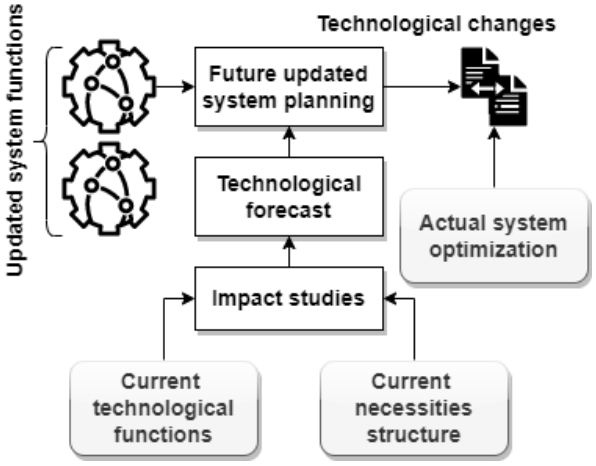

Figure 2. The processes characteristic of updating by planning

The optimization flow of current systems. In order to obtain updated functionalities, according to the described system, the importance of carrying out impact studies is noted in order to know in detail the future changes occurring at the level of the final sub-assemblies are suggestively illustrated in Figure 2. After the careful analysis of the expected results, it is recommended to make a technological prediction that takes into account the planning of all the activities provided as stages for the realization of the innovation functions. The result of all these steps will take the form of technical and technological changes through which the systems and equipment will benefit from the application of the appropriate maintenance techniques.

4 MAINTENANCE OPERATIONS PLANNING

The control techniques of the implementation stages related to the application of the maintenance features take into account a detailed planning including the update attributes. As the specific maintenance processes were perfected and updated, the production technology developed in a particular organizational context. Table 1 shows some of the factors that influence the ability to evolve from a technological point of view. Thus, four major stages corresponding to the incremental procedures will be considered: current, actual-improved, improved, a brand-new model. It goes without saying that for each update iteration, the conceptual model used will acquire specific attributes corresponding to the evolution of the maintenance methods and technologies used. Whether it is about increasing the company's competitiveness, possible internal reorganizations or expanding functional competencies, it is desirable to obtain an evolution at the level of applying current and effective maintenance plans.

The specific technical control takes into account both organizational and technical aspects of implementation. Establishing the values and allowed deviations for the quality parameters of reliability and maintainability contribute to a good allocation of specific activity limits. The definition of the works to be

performed and implicitly the responsibilities will constitute a basic stage in the verification of the concurrence between the current measured technical performances and ensuring the optimizations through updating.

The interrelation of stages such as product development, performing tests to demonstrate the fulfillment of objectives as well as final system checks is mandatory in the context of obtaining an application process of maintenance. In the case of the integration of prescriptive mechanisms, the character of the means of control must take an automated form for a good management of the prevention of defects. Also, on the basis of a program for the periodic verification of the technological parameters required for prescriptive maintenance plans, compliance with the limits imposed by the particularities of the equipment that is part of the internal structure of the monitored assembly is ensured. Efficient planning is given by good organization of execution and commissioning activities.

Novelty elements are introduced through the use of the latest generation computer technologies, such as Artificial Intelligence and knowledge-based reasoning. Of course, high-performance systems are dedicated to specific equipment and processes Building the availability model represents a first step in the generation of the overall architecture of the system. Checking the fact that a service is working at the required degree of reliability and if it is able to work in the same way throughout its lifetime represents a challenge of the current moment. Effective planning takes into account all cases of failure so as not to ignore the situations in which the results could be interpreted incorrectly. Often, bad results can lead to real successes after analyzing the steps that led to a dysfunctional implementation. These should be seen as learning experiences, thus accumulating applied knowledge on the field and model of maintenance. The planning must specify in detail all the operations undertaken at given moments of time (Ungureanu, 2015).

Table 1. Description of technical specifications in correlation with maintenance procedures.

Maintenance procedure	***Specification***
Existing	The current performance will suffer no changes.
	The competitiveness of the company will change, but not by very much, maybe for the worse.
Current-improved	Competitiveness can be improved in the short term. In time, the company may even be excluded from the market.
	The company stays competitive.
Improved	The company becomes more competitive.
	The company is diversifying by expanding the competencies it now has.
Brand-new	The company is undergoing a reorganization, which will involve new competencies. Competitively, the company's position is improving.
	General reorganization of the company that will expand to a new activity.

5 RESULTS ANALYSIS

The automatic and multidimensional control utilities can be assisted by computer systems and microprocessors, a fact that involves, on the one hand, directing the maintenance processes in such a way as to ensure that the characteristics and parameters fall within the established usage limits. On the other hand, the causes that determine the non-compliance with the validated parameters can be identified through the iterative process of each verification stage, present at the end of any operating operations cycle. Both endurance tests and reliability tests are elements of the control and standardization plans of the

maintenance system. Obviously, the technical analyzes of the monitored products or systems must be updated in accordance with the optimizations introduced by the new applied technologies.

The organization and improvement of the activities must focus mainly on the preventive and prescriptive maintenance plans due to the innovative character introduced at the level of the design of the new functional assembly. Technology is constantly evolving, a fact demonstrated over time by the great industrial developments and by the automation and digitization processes introduced at the level of assemblies that previously functioned in a primitive way, not reaching the expected level of efficiency and usefulness.

Frequently, the convention adopted between the operators responsible for ensuring the maintenance of the assemblies and equipment under management consists of simple, well-known, routine operation. The way in which the results of the preprocessing and production activities were obtained did not represent a major interest as long as the use was carried out within normal limits and the occurrence of various defects was minimized. With the introduction of the fourth industrial revolution, the maintenance processes have developed in the sense of focusing on the concrete, the continuous improvement of the manufacturing processes and the adoption of a modern management of the maintenance activity.

5.1 Implementation of innovative methods

The cost of obtaining quality and efficient products and services at the same time comes with the need to complete specific processes through the integration of new technologies, which bring added value as innovation. At the level of application of maintenance operations, there are multiple possibilities for innovation. Regardless of whether it is product or service innovation, major changes will be observed at the level of production or decision-making flows. From the point of view of product innovation, maintenance can take the form of a specialized computer program through analysis and guidance through clear directives aimed at weak points or elements of major importance in the context of interconnected assemblies.

The innovation of the services in this case implies keeping the current maintenance system as such, however, the need to modernize all intrinsic processes can be seen. In this way, the maintenance policy will include both the usage characteristics, the technical ones as well as the non-functioning losses, the dead times, due to the poor quality of the integrated services. Figure 3 systematically represents all the components that lead to obtaining a modern maintenance plan. The main components that are part of the preparation and including exploitation process are: materials, technologies, equipment, process controls, adequate planning and management of all reference elements. The present diagram highlights the essential elements that can contribute to the appearance of a manufacturing defect. Each of the six components can be decomposed in turn until the primary elements are reached, which require additional individual attention. The activity of improving quality, eliminating defects and predicting failures must be interpreted as a continuous improvement activity.

In the field of service quality, as in other fields, the identification of informational flows and their technical characteristics is an important activity for establishing particular requirements and objectives. In this sense, it is necessary to make a comparative difference between the external components and the internal flows between different levels. As a rule, the application of a certain maintenance plan is realized only after obtaining a feedback

based on the totality of the decisions applied at the level of the available resources.

Also, the evolution of maintenance systems is based on an entire process of identifying and maintaining the traceability of functional requirements. Recognition of the problem is identified as an opportunity to initiate the development process. Once the situation has been detailed, a decision will be prepared and adopted to establish an alternative course of action. The control of the results obtained after completing the mentioned steps will consist in the collection of partial solutions and in the specific filtering.

5.2 Recommendations for methodology application

A maintenance methodology can be applied in several ways, depending on priorities. Among these priorities can be mentioned the reduction of the downtime of the machine under maintenance, a detailed scheduling of the maintenance operations, the obtaining of the superior quality of the maintenance services, or a maximization of the reliability of the machine under maintenance. In order to obtain a modern maintenance process, oriented towards the reduction of dead times, a careful planning of resources is recommended.

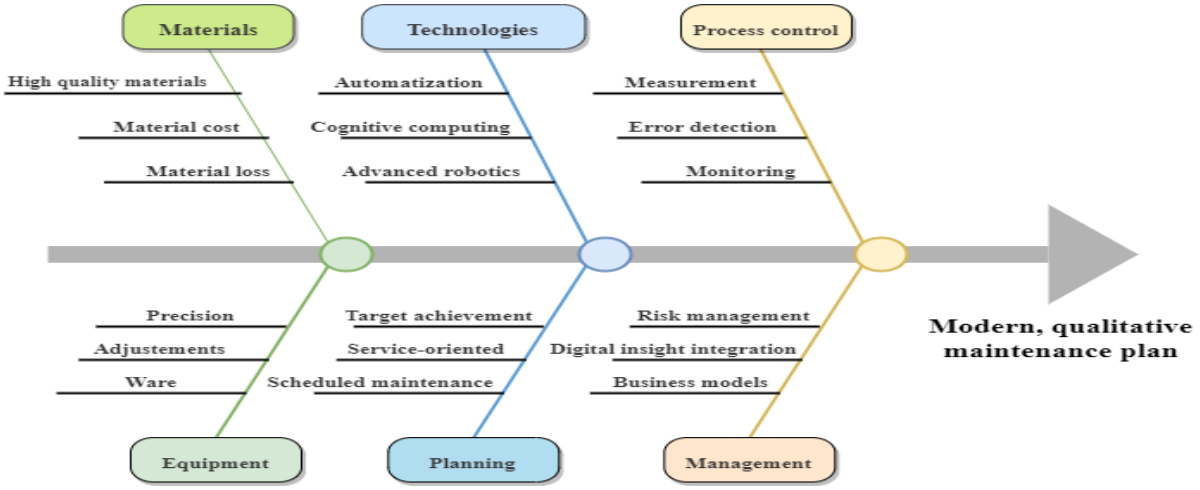

Figure 3. Efficient maintenance components which contribute to detecting errors

The utilities, techniques and technologies used to obtain a concrete maintenance plan are differentiated according to the purpose and the elements on which they are directed. According to Table 2, there are three fundamental categories of domains for the application of technical plans: raw materials, production and applications. Both management, long-term planning, and self-diagnosis components are noteworthy. From a technical point of view and production efficiency, appropriate materials and devices must be used that are fast and reliable.

In the design stage, perfecting the system is an integral part of the development of the entire industrial process. In the exploitation stage, perfecting the system is all the more necessary in the case of processes intended for use as means of work as well as long-term equipment. In this case, an improvement at the

device level leads to a better knowledge of the behavior in operation. The real-time processing of the data is imposed by the requirements of the quality management process in the conditions where the control is exercised during the development of the monitored activities. The data processing is carried out during the preceding maintenance processes and the information obtained can be used to make decisions regarding the management of the maintenance activity. However, it is recommended to organize the data structurally by storing them in databases specific to maintenance activities. In this way, consistency is ensured and an increase in efficiency is adopted from a temporal point of view.

Table 2. Characterization of specifications according to utility and technology

Maintenance technological specification	***Purpose***	***Implementation methods, techniques and tools***
Raw materials	Technical	Proper materials and machinery
	Economical	Energy efficient machinery and low material loss
Production	Efficiency	Fast and reliable equipment
	Cost reduction	Material management
	Profit	High quality product
	Time saving	Automation processes
Applications	Valid results	Result cross-check
	Minimal errors	Long-term planning
	Complex analysis	Quality and production control
	Self-diagnosis	Technological failure detection and forecasting

6 CONCLUSIONS

The set of relationships that a particular enterprise wants to establish with the specific development environment, respectively with the industrial sector in which it operates must be updated, in direct connection with new trends and methods. The implicit strategy to which the organizational environment must refer must refer to obtaining correct results, improved through the use of advanced technologies. The economic and technical possibilities are decisive factors in the adoption of new strategies, aiming at changes in the activity carried out. The hierarchization of technologies through the prism of the ensemble that realizes the products constitutes a first stage of obtaining the productivity of the research activity. For the stage of updating the organizational capabilities, it is equally important not to be limited to a few technologies related to limitations in the respective fields. As a rule, changes and improvements, even minor ones, brought everywhere where possible, can provide remarkable subsumed results.

Anyway, the technological advance gained must be maintained for a longer period than the time required for implementation in order to be able to put it into practice. Once the general strategy of the organization is established, it is possible to proceed to the establishment of the technological strategy for the application of maintenance. In this case, the identification of all existing technologies on the flow that create added values is an essential criterion for choosing development directions. It is demonstrated that a high degree of technological uncertainty only implies disadvantages at the level of adopting the maintenance strategy.

Technologies grow when scientific and technical knowledge allows it, they develop to the extent that the product or service responds to a particular need and disappear when

another more efficient technology eliminates it. In this case, during each iteration of incremental development, the desire and implicitly the need to update the applied maintenance plans is identified. The knowledge and analysis of the existing system, the definition of the requirements of the new system, as well as the design of the defined conceptual model constitute a complex methodology for updating and optimizing the current performances. Considering the laborious nature of the maintenance activities, it is recommended to identify the problems and establish a unitary way of working. In the context of new technologies, the maintenance activity should not be limited strictly to the repair or remediation of malfunctions, but should establish predictions for possible future failures.

Correlation of the applied maintenance plans with the last generation technologies only bring benefits regarding the good management of the equipment and systems used. In this way, the need to update the types of maintenance applied to systems with current trends is highlighted. A lack of potential in bringing the applied methodologies up to date can create unpleasantness at the level of obtaining the final results. As future directions of research on the topic of updating the multitude of maintenance technologies applied in the organizational environment, the possibility of introducing elements specific to digitization such as complex and high-performance computational techniques is noteworthy. Of course, the specific technologies of Artificial Intelligence, the integration of large databases and the processing of data obtained from sensors located in key points must be taken into account. In order to obtain a modern management of the maintenance activity, the use of integrated IT management systems for industrial units is recommended.

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