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PROPOSAL FOR A GENERAL CLASSIFICATION OF MAINTENANCE APPROACHES

Abstract. This research paper addresses the pressing need for a universally accepted classification of maintenance types, as current classifications vary significantly across institutions, organizations, and countries. Despite extensive research in the field of maintenance, a standardized framework remains elusive, leading to confusion and inefficiencies in maintenance practices. The primary objective of this study is to develop a comprehensive classification of maintenance types that can be widely adopted. Through a thorough literature review, various maintenance approaches have been identified and analyzed, laying the groundwork for a new classification system. This paper presents a proposal for a general classification of maintenance approaches.
Keywords: maintenance, maintenance classification, maintenance approach.

Introduction. The continuous evolution of the industrial manufacturing domain has significantly influenced the practices and strategies employed in manufacturing processes. Manufacturing has undergone significant automation, with many industries striving for fully automated processes. Automation is accompanied by the introduction of an increasing amount of equipment, which, in turn, is becoming more complex in both design and control.

Manufacturing equipment are in general subject to degradation because of usage and exposure to environmental factors. This degradation along with other factors such as aging, poor equipment design, operational errors, usage intensity etc., ultimately leads to equipment failure which could result in safety issues, equipment damage, produced goods quality issues, and unexpected machine unavailability [1].

Since the physical condition of equipment significantly impacts product quality and production efficiency it is essential to establish proper maintenance in order to minimize the possibility of its failure.

International Organization for Standardization defines maintenance as combination of all technical and administrative actions, including supervisory actions, intended to retain an item in, or restore it to, a state in which it can perform a required function [2].

Traditionally, maintenance has been seen as an inevitable source of cost. In 2020, 46.91% of surveyed companies in North America reported that they spent from 21% to 40% of their operating budget on maintenance of their equipment and supplies. Meanwhile, 35.67% spent 1% to 20% of their budget. On the other hand, 2.25% of companies spent more than 80% of their operating budget on equipment maintenance alone [3].

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Considering maintenance direct and indirect influence on production objectives and company's profitability it is increasingly seen as a strategic function. When implemented effectively, maintenance could result in great savings and increased profit [4], [5].

In spite of being an important constituent of any production system and a subject of many researches, maintenance still has been classified in many different ways.

Analysis of the latest research and publications. Before continuing with a literature review it is important to introduce the definition for maintenance approach (type). This research defines maintenance approach as a methodology employed to achieve maintenance objectives. While most sources use a term «strategy» to describe the same notion, we think of «strategy» as something wider and more complex, involving a combination of different approaches to form an optimal maintenance action program. Maintenance strategy is unique to each facility and industry, while maintenance approach is a general perspective on how maintenance is done. An example of maintenance strategy can be a Reliability-Centered Maintenance (RCM), but this is out of scope of this research.

At first, different standards and other official documents covering the question of maintenance classification have been researched. A short overview of classifications found in those resources is provided bellow.

The classification proposed by ISO [2] defines two main categories of maintenance: corrective and preventive (Fig. 1).

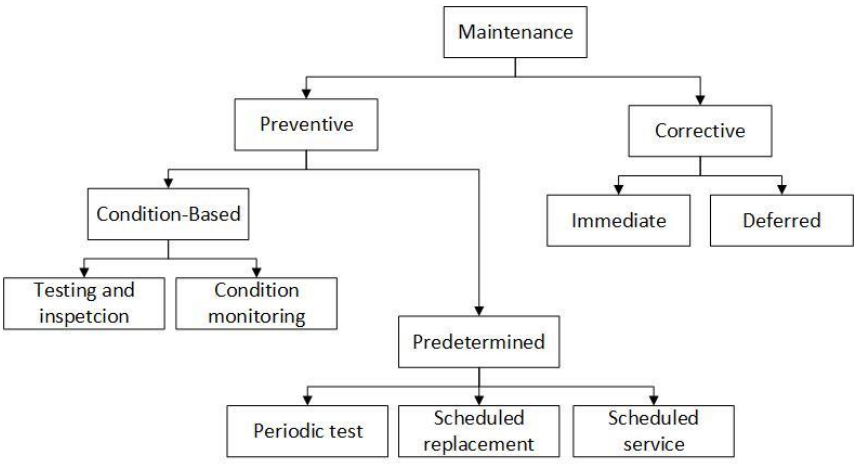

Figure 1 – Maintenance categories according to [2]

As can be seeing from the figure 1, ISO basically classifies maintenance into two general categories with some sub-categories. The preventive type is subdivided into condition-based and predetermined maintenance types, and corrective maintenance is further categorized into immediate and deferred sub-types.

The United States Department of Energy classifies four approaches to maintenance [6]:

- reactive;
- preventive;
- predictive;
- reliability centered (RCM).

The version of classification of maintenance proposed by the European Standard EN 13306:2017 [7] specifies maintenance as shown in figure 2.

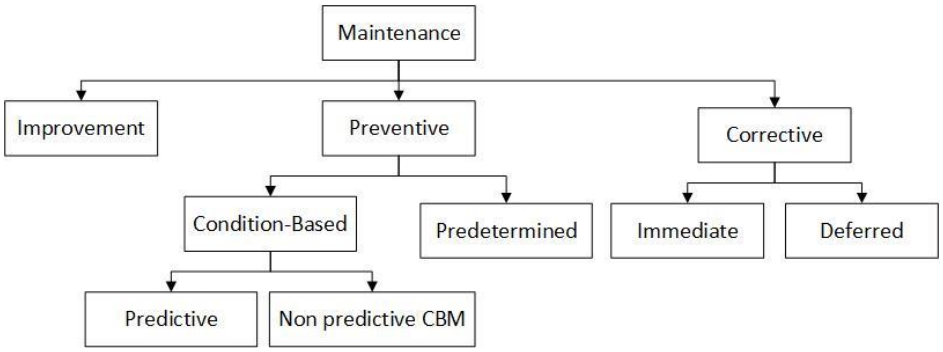

Figure 2 – Maintenance classification according to [7]

Then, papers, books and other sources like conference proceedings have been scrutinized. A brief review of the material is provided in the following paragraphs.

Figure 3 depicts the hierarchical structure of different maintenance types proposed by the authors of [8].

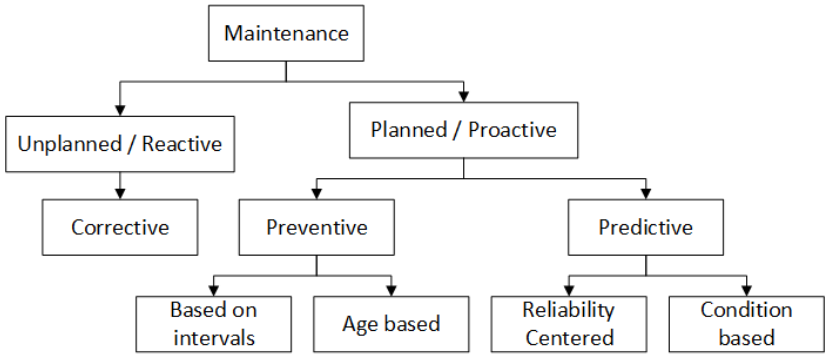

Figure 3 – Maintenance hierarchy according to [8]

According to [9] there are three basic maintenance approaches: reactive, proactive and aggressive. A more exhaustive and consequent classification of different maintenance types devised in [9] is in figure 4.

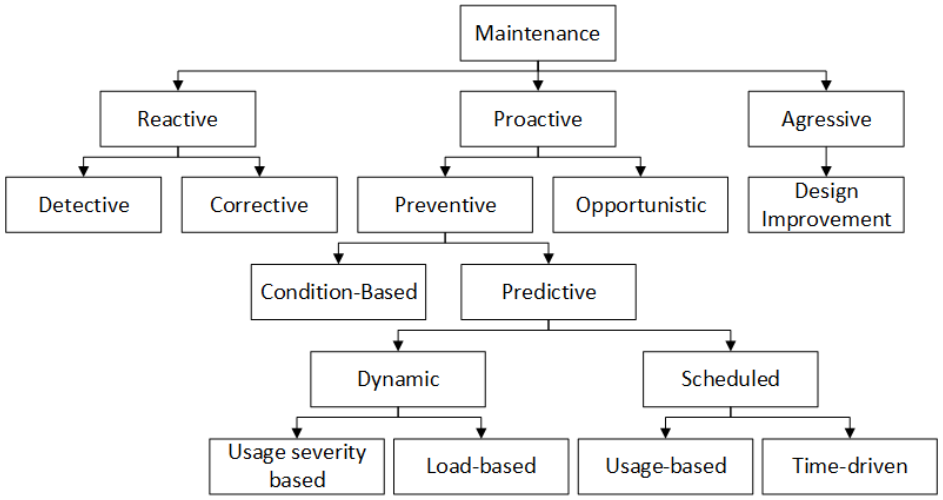

Figure 4 – Maintenance classification according to [9]

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Reactive strategies are described here as a fire-fighting approach, where maintenance activities are provoked by actual failures. Proactive strategies, on the other hand, are meant to prevent breakdowns using a range of methods to predict equipment deterioration and undertake preventive tasks to restore equipment to a proper condition. Aggressive approach is defined as one that aims to enhance a system by modifications or redesign [9].

Keith Mobley in his book «Maintenance Fundamentals» states that there are three main types of maintenance: corrective, preventive and improvement. Structure of maintenance presented in [10] illustrated in figure 5.

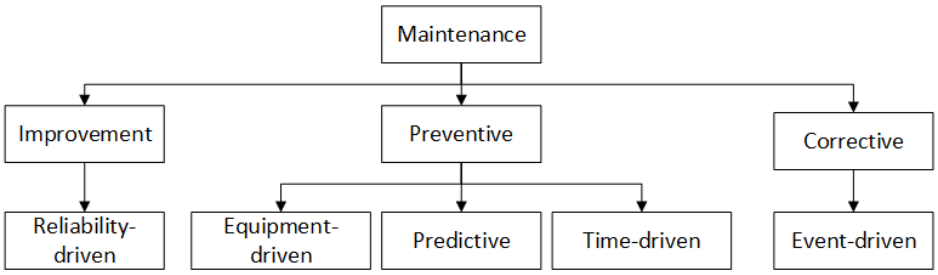

Figure 5 – Maintenance classification according to [10]

In [11] maintenance is classified in terms of the time when a repair is performed relative to the occurrence of a failure. According to this paper, there are three basic approaches to maintenance:

- corrective;
- preventive;
- predictive.

A classification given in the [12] (Fig. 6) as well as those in [9] and [10] includes a type of maintenance that is based on improvement and modification of an assets. Design-Out Maintenance (DOM) focuses on the design correction in order to eliminate the cause to maintenance [12].

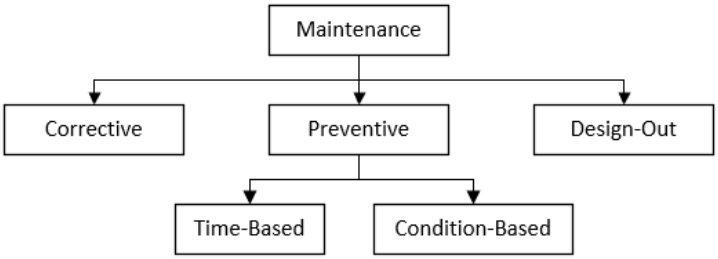

Figure 6 – Types of Maintenance according to [12]

The analysis done by authors of [13] showed that maintenance may be classified as shown in figure 7.

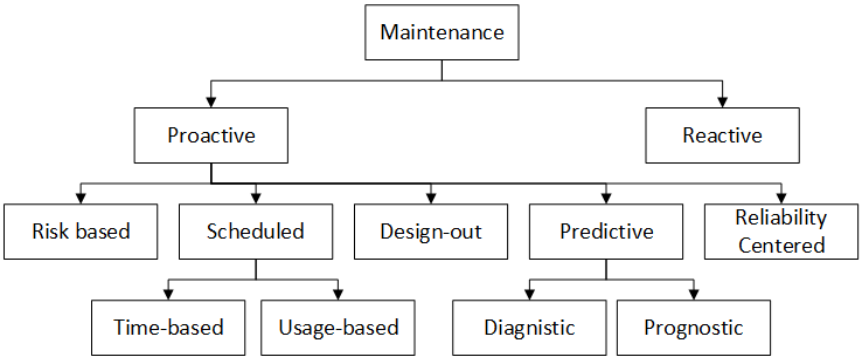

Figure 7 – Maintenance classification according to [13]

In [14] authors also distinguish two major maintenance types: corrective and preventive (Fig. 7).

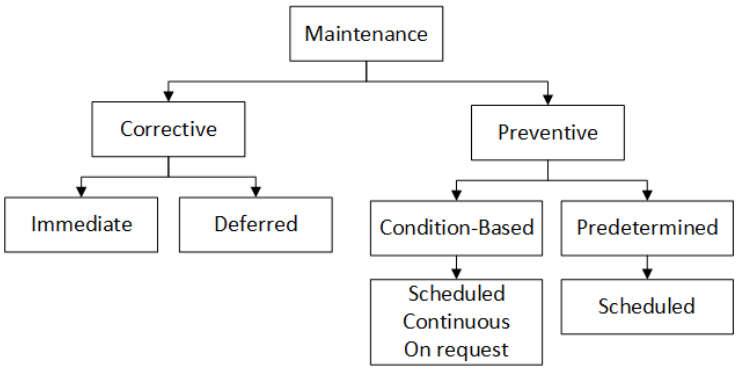

Figure 8 – Maintenance classification according to [14]

Authors of [15] conducted an extensive research of maintenance classifications and different viewpoints on this issue developed over the years and based on their findings proposed their view on maintenance taxonomy (Fig. 9).

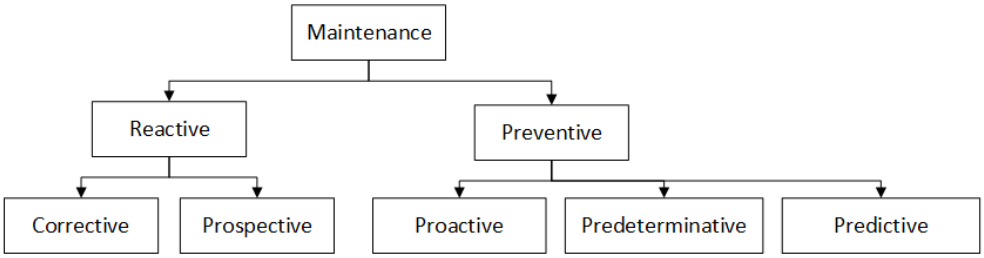

Figure 9 – Maintenance taxonomy proposed by [15]

Here, they like others classify maintenance into two major types. In this case they are reactive and preventive. Unlike others, the reactive approach has been further classified into two sub-classes: corrective and prospective. The prospective maintenance is defined as preventive work that is due and overdue is done when failure force the system to stop [15] They also call this type of maintenance – opportunistic maintenance. The defined maintenance types are further classified into different tactics, but this is not in the scope of our research.

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The literature review showed that a variety of classifications for maintenance have been developed over the years and each differs to some extent from the others. A summary of a reviewed literature is provided in table 1.

Table 1

Summary of reviewed material

	Maintenance type									
Source	Corrective	Preventive	Condition-based	Predetermined	Reactive	Predictive	Reliability centered	Improvement	Proactive	Opportunistic
[2]	+	+	+	+						
[6]		+			+	+	+			
[7]	+	+	+	+		+		+		
[8]	+	+	+		+	+			+	
[9]	+	+	+		+			+	+	+
[10]	+	+				+		+		
[11]	+	+				+				
[12]	+	+	+					+		
[13]					+	+	+	+	+	
[14]	+	+	+	+						
[15]	+	+		+	+	+			+	+

Problem Statement and Research Objective. As a literature survey showed, despite of many researches done in the field of maintenance, there is still no generally accepted classification of maintenance. Different institutions, organizations and researchers in different countries classify and standardize maintenance in their own way. So, there is a need to establish a universal classification for maintenance types that would be comprehensive and could be accepted worldwide.

The main objective of this research paper is to devise a classification for maintenance types that would be comprehensive and could be widely accepted.

Presentation of the main material of the research. This section researches maintenance approaches identified in the literature review to develop a more comprehensive understanding and further establish a new classification.

Despite all of the of the reviewed classifications differs, virtually all of them encompasses two main types of maintenance: corrective and preventive. So, it's safe to say, that there is a consensus about these two approaches being key maintenance types.

Corrective maintenance is also referred reactive, breakdown, run-to-failure, failure-based, or emergency maintenance [16], [17], [18], [19], [20]. This is a type of maintenance approach where the corrective intervention, like repair or part replacement, takes place only after failure event has occurred [20], [21].

Unlike the corrective (reactive) approach, which addresses failures only after they occur, preventive approach focuses on proactive measures to reduce the likelihood of equipment failure. Instead of intervening only when a failure happens, this type of maintenance emphasizes preventive actions aimed at maintaining equipment reliability [22].

Some of the sources, like [8] or [9] classify one of the root types of maintenance being proactive. It may look like it has the same meaning as preventive, but it is a broader term for a a higher maintenance type in the hierarchy. It's said that proactive maintenance utilizes preventive and predictive maintenance activities to prevent equipment failures from occurring [20].

Predetermined maintenance is formally defined as a type of maintenance carried out in accordance with established intervals of time or number of units in use [7], hence it is sometimes referred as scheduled maintenance. The scheduling is usually based either on hours of operation (then it's called a Time-based maintenance) or other quantitative usage indicators (then it's called Usage-based maintenance), like the number of times an item has been used, the number of kilometers the items has been used, etc. regardless of the current item state [14]. In the reviewed materials such approach is categorized as a type of preventive approach.

Condition-based maintenance (CBM) is a type of preventive maintenance which include assessment of physical conditions, analysis and the possible ensuing maintenance actions [7]. It is clearly seen that CBM is a type of preventive maintenance approach and so should be categorized accordingly.

The next approach to be looked at is predictive. Predictive maintenance is an approach that makes maintenance decisions based on the real machine health conditions [23]. The definition given in [7] states that predictive maintenance is a condition-based maintenance carried out following a forecast derived from an analysis of item's parameters. Here we can conclude that predictive maintenance is a derivative of a condition-based maintenance.

Improvement or modification is not always considered as a maintenance activity. [2] states that modification is not a maintenance category, but at the same time it is noted that this kind of task is often performed by maintenance organization. Since modification or improvement is done in order to prevent failures it may be considered as a preventive maintenance action, and therefor may be placed under a preventive maintenance category.

Opportunistic maintenance is a type that is not often find it the related literature. As was mentioned before, this type of maintenance that is done when an opportunity appears (hence the name), and it usually involves preventive activities.

Based on the reviewed classifications and the approaches identified within them, along with descriptions of those defined approaches, a new classification for maintenance has been developed (Fig. 10).

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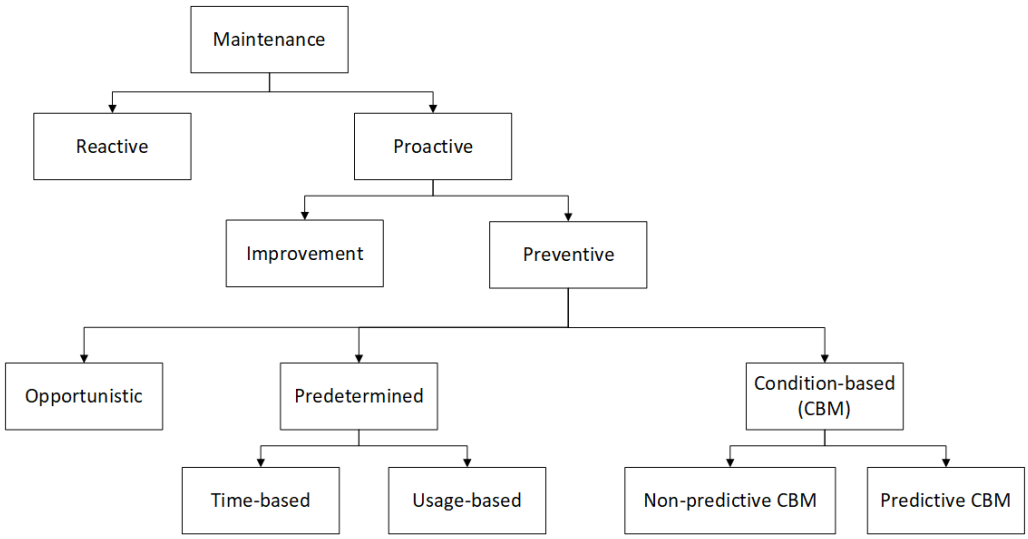

Figure 10 – Proposed maintenance classification

Conclusion. The research highlights the need for a universally accepted classification of maintenance types due to the diverse and often inconsistent categorizations currently in use across various institutions and industries. A comprehensive literature review has been done to determine what classifications exist and what types of maintenance they encompass. This study aims to bridge the gap in maintenance classification by proposing a comprehensive framework that include these approaches while allowing for the integration of emerging methodologies. By establishing a universal classification, organizations can enhance their maintenance strategies, ultimately leading to improved operational efficiency, reduced downtime, and increased profitability. The findings of this research serve as a foundational step towards achieving a more cohesive understanding of maintenance practices, which is crucial for the advancement of the manufacturing sector in an increasingly automated and complex industrial landscape.

Further work should include more detailed research into defined maintenance approaches, with particular emphasis on the predictive approach as it as it represents a cutting-edge approach that can significantly reduce unexpected downtime and optimize equipment lifespan. Future studies should focus on the implementation challenges of predictive maintenance, such as data collection, sensor integration, and algorithm accuracy.

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Загальна класифікація методів технічного обслуговування

Робота присвячена дослідженню існуючих класифікацій для методів технічного обслуговування. Незважаючи на значну кількість проведених дослідження в галузі технічного обслуговування, загальноприйнята класифікація досі не розроблена. Основною метою цього дослідження є розробка універсальної класифікації видів технічного обслуговування, яка могла б стати загальноприйнятою. Провівши ретельний огляд літератури, в якій порушувалось питання класифікації методів технічного обслуговування, було виявлено та проаналізовано різні класифікаційні системи. На основі виявлених систем класифікації та тих методів ТО, які в них зазначались було запропоновано нову універсальну систему класифікації.

Ключові слова: технічне обслуговування, методи технічного обслуговування, класифікація

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