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UNIVERSAL CLASSIFICATION FOR MAINTENANCE APPROACHES

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Abstract. *This study tackles the issue of inconsistencies in maintenance classifications across various institutions, industries, and regions, highlighting the absence of a generally accepted classification of maintenance approaches despite extensive research in the field The primary goal of this research is to propose a comprehensive and universally applicable classification of maintenance approaches. Through an in-depth review of existing literature, diverse maintenance methodologies were identified, evaluated, and synthesized to form the basis of a new classification framework. This paper introduces a general classification that integrates key maintenance types, aiming to provide clarity and consistency.*

Keywords: *maintenance, classification, maintenance approach*

As industrial automation continues to evolve, the machinery used in manufacturing has become more complex and abundant. This makes proper maintenance not just important, but essential for keeping operations safe, reliable, and efficient. Over time, equipment naturally wears down due to usage, age, and environmental conditions, which increases the risk of breakdowns and can negatively affect both product quality and overall costs. Although maintenance is widely accepted as a key part of any industrial strategy, how it's defined and categorized can vary significantly between different organizations, standards, and studies—leading to confusion and inconsistent practices. This paper aims to clear up that confusion by offering a unified framework for classifying maintenance strategies, grounded in an extensive review of existing literature, to support more effective and streamlined maintenance efforts in today's manufacturing environments.

There has been done a literature review that revealed how much existing classifications of maintenance approaches distinct from each other.

The ISO standard [1] divides maintenance into corrective and preventive categories, with preventive further split into condition-based and predetermined types, and corrective into immediate and deferred subcategories. The U.S.

Department of Energy [2] proposes four approaches: reactive, preventive, predictive, and RCM. Similarly, the European Standard EN 13306:2017 [3] classifies maintenance into corrective and preventive types, incorporating condition-based and improvement-oriented subcategories. Academic sources add further variety: [4] outlines a hierarchy including corrective, preventive, and proactive approaches; [5] describes reactive, proactive, and aggressive strategies, with the latter focusing on system enhancement; [6] emphasizes corrective, preventive, and improvement maintenance. [7] focuses on corrective, preventive, and predictive types. In [8] authors introduce Design-Out Maintenance (DOM), which, they say, in an approach aimed to eliminate a root causes of maintenance. [9] proposes a reactive-preventive taxonomy, uniquely including opportunistic maintenance as preventive work performed during unplanned downtime.

Table 1 consolidates these classifications, highlighting the absence of a universal framework and underscoring the need for a standardized approach to unify maintenance terminology and practices.

Table 1

Maintenance Types from Literature Review

	Maintenance type									
Source	Corrective	Preventive	Condition-based	Predetermined	Reactive	Predictive	Reliability centered	Improvement	Proactive	Opportunistic
[1]	+	+	+	+						
[2]		+			+	+	+			
[3]	+	+	+	+		+		+		
[4]	+	+	+		+	+			+	
[5]	+	+	+		+			+	+	+
[6]	+	+				+		+		
[7]	+	+				+				
[8]	+	+	+					+		
[9]	+	+		+	+	+			+	+

Building on the insights from the literature review, this study proposes a comprehensive classification of maintenance approaches to address the inconsistencies observed across existing frameworks. The proposed structure (Fig. 1) integrates widely recognized maintenance types into a unified hierarchy,

emphasizing clarity and adaptability. At its core, it retains the two foundational categories — reactive (or corrective) and proactive. Reactive maintenance defined as a maintenance approach that involves corrective actions triggered by the actual equipment failure. Proactive maintenance is aimed at averting failures. It is subdivided into predetermined, condition-based (driven by real-time equipment health assessments), and improvement-oriented (focused on asset's design modifications to enhance its reliability) approaches. Predictive maintenance is classified as a subset of condition-based maintenance, leveraging data-driven forecasts to optimize interventions. Opportunistic maintenance is included under preventive maintenance, reflecting preventive tasks performed during unscheduled opportunities, such as downtime.

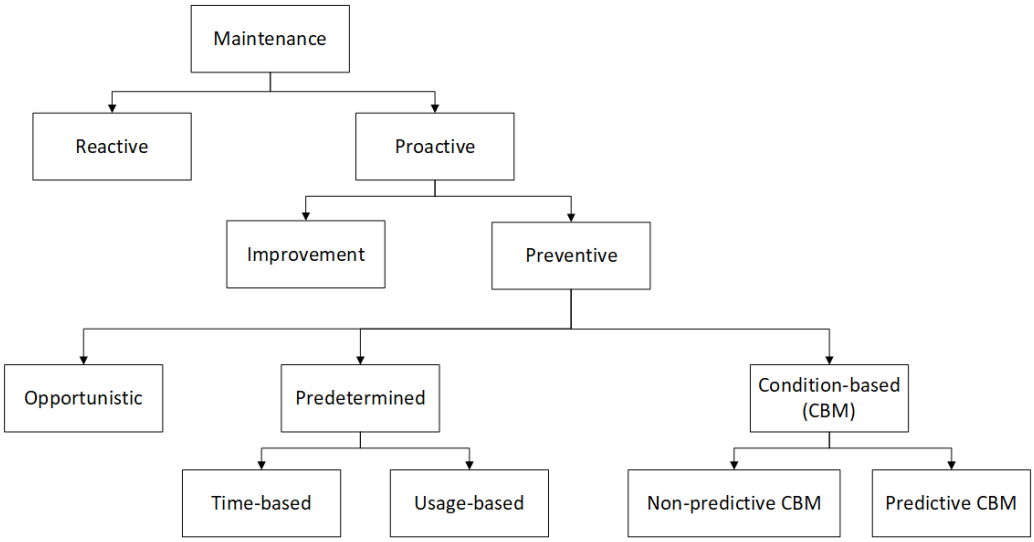

Figure 1 –– Proposed maintenance classification structure

In the proposed classification we tried to balances between simplicity and comprehensiveness. By organizing maintenance approaches in such hierarchical way, the framework provides a clear universal reference point for maintenance practitioners and researchers.

Conclusion. The general classification framework proposed in this paper seeks to harmonize the diverse approaches to maintenance found in both academic and industrial contexts. It provides a foundation for further research and standardization efforts in maintenance engineering and management.

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УНІВЕРСАЛЬНА КЛАСИФІКАЦІЯ МЕТОДІВ ТЕХНІЧНОГО ОБСЛУГОВУВАННЯ

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Анотація. *Це дослідження розглядає проблему непослідовності в класифікаціях методів технічного обслуговування серед різних установ, організацій та дослідників. Визначається відсутність загальноприйнятої класифікації підходів до технічного обслуговування, незважаючи на широкі дослідження в цій галузі. Основною метою цього дослідження є розробка універсальної класифікаційної схеми для підходів до технічного обслуговування. Проведений огляд існуючих джерел, дозволив ідентифікувати та проаналізувати різноманітні класифікаційні схеми та методо технічного обслуговування, на основі чого було сформовано основу нової класифікаційної структури. У цій роботі представлено універсальну класифікацію, яка інтегрує ключові типи технічного обслуговування.*

Ключові слова: *технічне обслуговування, класифікація, підхід до технічного обслуговування*

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