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Is Sustainable Maintenance A Support- Or Standalone Function? A Definition

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Abstract

Sustainability is getting more and more attention in society, industry, and research. Companies are increasingly focusing on sustainable practices to meet different requirements. Industrial maintenance, which tends to be considered sustainable, is now more frequently examined in research for its actual sustainability, and various approaches to the design of maintenance are being presented. In this context, the term sustainable maintenance is not uniformly defined. There are different underlying assumptions about the term sustainability within the maintenance function itself, whether it is a support-function to enable sustainable manufacturing or a standalone function to improve sustainability in manufacturing companies by itself. For this reason, this study defines the term Sustainable Maintenance based on previous publications. For this purpose, a systematic literature review of 46 publications identified as relevant to the topic is conducted, and then a definition is derived via the Genus Proximum et Differentia Specifica by Aristotle through the distinction of sustainable maintenance from traditional maintenance.

Keywords

Sustainable Maintenance; Sustainable Manufacturing; Industry 4.0; Stakeholder Theory; Triple Bottom Line

1. Introduction

In today's world, companies face a wide variety of challenges, such as scarcity of physical resources, stricter laws and regulations, customer demand for high-quality products, and economic stagnation [1]. Challenges such as the shortage of natural resources and the growing focus on environmental concerns pose problems for companies, which can however lead to competitive survival and even competitive advantage in response to regulations [2]. Incorporating sustainability into corporate strategies is referred to as Sustainable Development when the current needs of the company and those of their stakeholders are met while focusing on protecting the environment and society [3].

Sustainability is a challenge for manufacturing companies that can lead to better product quality, increased market share, and increased profits [4]. In this context, sustainable maintenance activities have also come into focus, which, in addition to the traditional technical and economic dimensions, also consider the environmental and social ones [5].

Maintenance influences the productivity and, consequently, the profitability of companies through a direct impact on efficiency, effectiveness, and quality of actions, which are considered key elements of adequate maintenance strategies [6]. In fact, maintenance actions influence not only the technical dimensions of production systems, i.e., reliability and availability, as well as product quality, but also the three sustainability dimensions: environmental, economic, and social. [7]

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Sustainable maintenance has no clear definition but is often described as a process that achieves the condition of the objects to be maintained through technical measures [4,8] and prevents negative ecological impacts [9,8,10] the safety of employees [8,4,10] and stakeholders [9] and is economically sound [9,8] and thus also ensures the competitiveness of the company [11].

In current research, the importance of considering sustainability aspects in industrial maintenance is increasing for various reasons outlined above. The number of publications on this subject has been growing steadily in recent years. Existing definitions of the term overlap, but also complement each other and are thus not unambiguous. This paper therefore answers the following research question: **How can Sustainable Maintenance be defined?** A question that derives from the definition of Sustainable Maintenance is, whether in the existing literature it is seen as a standalone or a support function. A support function would be a support function to allow the company to design the manufacturing process sustainably, with a focus on manufacturing. As a standalone function however would itself be able to independently help the company to become more sustainable. The basis for this is provided by a systematic literature review, while the definition itself is formulated based on Aristotle's Genus Proximum et Differentia Specifica. This approach originates from [12], who developed a definition of Industry 4.0 in their paper. The methodological approach is presented in chapter 2 while the evaluation of the systematic literature research follows in chapter 3.1. Subsequently, in chapter 3.2 the definition is presented.

2. Methodology

The following section describes the methods used to develop a definition for sustainable maintenance.

2.1 Systematic Literature Review on Sustainable Maintenance

A systematic literature review differs from traditional narrative literature reviews in that it is a scientific, transparent, and reproducible process, minimizing subjective bias through extensive literature searches and detailed descriptions by researchers of their procedures, decisions, and conclusions [13]. This method enables efficient and high-quality identification and evaluation of the literature on a selected topic [13] and helps identify key questions [14].

According to [13] a systematic literature search is performed in three steps. At the beginning, the research must be planned. For this, a conceptual discussion of the research problem and a description of the significance of the problem is included in the research protocol. A specific research question is not required. The goal of the first step is to have a research protocol that does not limit the creativity of the researcher in the review process, but still limits the possibilities of subjective bias. The second step is to conduct the literature search. For this, a literature search was conducted in the Web of Science, EBSCO Host, SCOPUS, and Emerald Insights databases using a pre-developed search string. The results were sorted according to inclusion and exclusion criteria [15] which were derived from the studies of [16] and [17], categorized and expanded by forward and backward searches [15]. In the third and final step, the results of the systematic literature review are summarized. For this purpose, on the one hand, a descriptive analysis is presented, which includes metadata of the study, and on the other hand a content analysis, which enables a solution of the research problem formulated at the beginning. [13]

A total of 46 articles were identified as relevant in the systematic literature search conducted on June 1, 2022. After identifying the relevant studies to the predefined research problem, the metadata of the studies and their content were evaluated. The evaluation included the country of origin of the authors and the year of publication [13] as well as the method on which the study was based and a classification of the result. [17,18,13]. For the content analysis of the publications, the method used by [12] for the definition of Industry 4.0 was applied. For this purpose, like the development of the search string, keywords were assigned to the

studies that were used to describe sustainable maintenance in the respective works. These are later used for the description of the species-forming difference.

2.2 Genus Proximum et Differentia Specifica

For the definition of the term sustainable maintenance, the genus Proximum et Differentia Specifica was chosen. A definition is a statement composed of the particular genus of the term to be defined and the difference from other terms of that genus [19]. Defining helps to identify a thing that is known by name but not by explanation [19]. According to this procedure, a thing is defined by its genus (the next higher class) and its differences from other things under the genus [20]. The definition must be unique to the thing being defined and must always be true, so definitions do not include properties that are true of both the thing being defined and other things in the genus [20].

In order to define according to the Genus Proximum et Differentia Specifica, the general generic term must first be determined. In this case the term "maintenance" was chosen according to [21]. Subsequently, a division of the generic term into more general, specific terms is chosen until the species term cannot be further divided. The decisive factor is which characteristics are chosen to distinguish the species terms. According to the description of maintenance as well as sustainability, the characteristics for differentiation refer to tasks and goals of the respective maintenance type. The type to be defined is "sustainable maintenance" while the comparison to traditional maintenance is presented.

3. Results

The following two chapters will present the results of the research process. In chapter 3.1, the results of the systematic literature review are presented, including the definition of traditional maintenance as well as identified definitions and descriptions of sustainable maintenance. Chapter 3.2 then presents the newly developed definition of Sustainable Maintenance, based on the Genus Proximum et Differentia Specifica described in chapter 2.2. The keywords assigned to sustainable maintenance that differentiate this from traditional maintenance are described more closely in chapters 3.2.1 to 3.2.5.

3.1 Systematic Literature Review

The papers identified as relevant in the systematic literature review are presented descriptively. The first study identified as relevant dates back to 2012. Overall, there is an increasing trend, although there is still a low number of publications on sustainable maintenance for the year 2022 due to the timing of the search in June 2022. With a total of seven publications on sustainable maintenance, Jasiulewicz-Kaczmarek offers the most publications, while Franciosi and Miranda have six publications on this topic. The majority of publications come from Europe, followed by Asia and Oceania.

Many of the studies analysed show the status quo of sustainable maintenance, while some also present new methods and models or theoretical frameworks. Tools for implementing sustainable maintenance have been published less frequently. Methodologically, researchers have often taken a theoretical approach, while some have also conducted research through case studies, expert interviews, or workshops. There has been no experimental research.

For the evaluation of the relevant publications, keywords were assigned to them that were used for the description of sustainable maintenance in the same. In the following, traditional maintenance is described according to the identified publications, its development in recent years and the relationship between maintenance and sustainability, to then be able to present the differences between traditional maintenance and sustainable maintenance in the sense of the genus proximum.

Traditional maintenance

Maintenance is the combination of all administrative, technical, and management actions during the life cycle of an object with the goal of maintaining or restoring the object to its functional state [22-26,5,27]. Therefore, the objectives of maintenance activities include high reliability and availability of equipment, as well as efficiency [28] and safety [26]. The implementation of maintenance activities influences product quality [1]. Nevertheless, maintenance is often perceived as a support process that has the production department as its only customer and is thus considered a cost factor [29]. The large number of machines leads to a high complexity of today's maintenance [5] which is influenced by the structure and organization of a manufacturing company [30]. Despite the perception as a cost factor in the company, maintenance is a component of most manufacturing companies, which ensures the functions of the production systems, which are necessary for an efficient production process [24].

Maintenance helps to minimize production costs and maximize equipment life corrective or preventive [31], maximize [6] thereby improving the performance [11] and profitability [24] of the entire company [4]. This includes improving the reliability of equipment, understanding the reasons for poor performance, preventing breakdowns, and reducing downtime by repairing [31]. At the same time, neglected or poorly performed maintenance leads to losses for the company [24] making it a critical function for production [11]. For example, equipment failure leads to increased repair costs, decreased quality of products, and overall shutdown of the production line [10]. Conventional decision-making approaches to maintenance strategies focus mainly on technical and monetary criteria [32].

While, as described above, maintenance as a function in manufacturing companies has been an area for outsourcing strategies and has been described as a cost driver [6], there has been an evolution in recent years together with production processes from a reactive function to a cost saving and value adding preventive, then to a green approach and is now seen as an area that should be managed sustainably [16]. Maintenance has also become critical for reliability and availability of assets due to the growing complexity resulting from the evolution of technologies, with a new task to avoid unexpected shutdowns due to digitalization [33].

The indicators described do not address the social and environmental aspects of maintenance [23]. However, it is essential to consider these aspects, as the condition of production facilities has an influence on occupational safety, the quality of the products to be produced or emissions [23]. Poorly performed maintenance leads, for example, to the emission of hazardous substances into the environment, the generation of waste due to a non-functioning system, inefficient consumption of resources and energy, and waste of stored materials [23,32].

Sustainable maintenance

A total of 190 keywords were assigned to the 46 publications. The frequency of assignment of the most frequently mentioned keywords is shown in Table 1.

Table 1: Most frequently found keywords for Sustainable Maintenance

Keyword	Frequency
Triple Bottom Line	28
Sustainable Manufacturing	26
Integrated View	11
Efficiency	10
Stakeholder	8
Quality	7
New Technology	5
Optimization	4
Availability	1

The keywords presented do not necessarily correspond to the species-forming difference, but purely to the description of sustainable maintenance. As an example, availability and downtime can be mentioned, which also belong to the objective in traditional maintenance and thus do not represent a difference.

The keywords identified and categorized here are a description of the sustainable maintenance used to derive the species-forming difference.

3.2 Definition of Sustainable Maintenance

For the definition of sustainable maintenance, the species-forming difference between sustainable and traditional maintenance is formed. This was developed from the keywords in this case. The keywords of levels two and three are specifications of the higher levels, so they are shown for clarification, but not included in the definition of sustainable maintenance. Referring to the definition of traditional maintenance, the keywords can be used to show the species-forming difference. This is shown graphically in Figure 1.

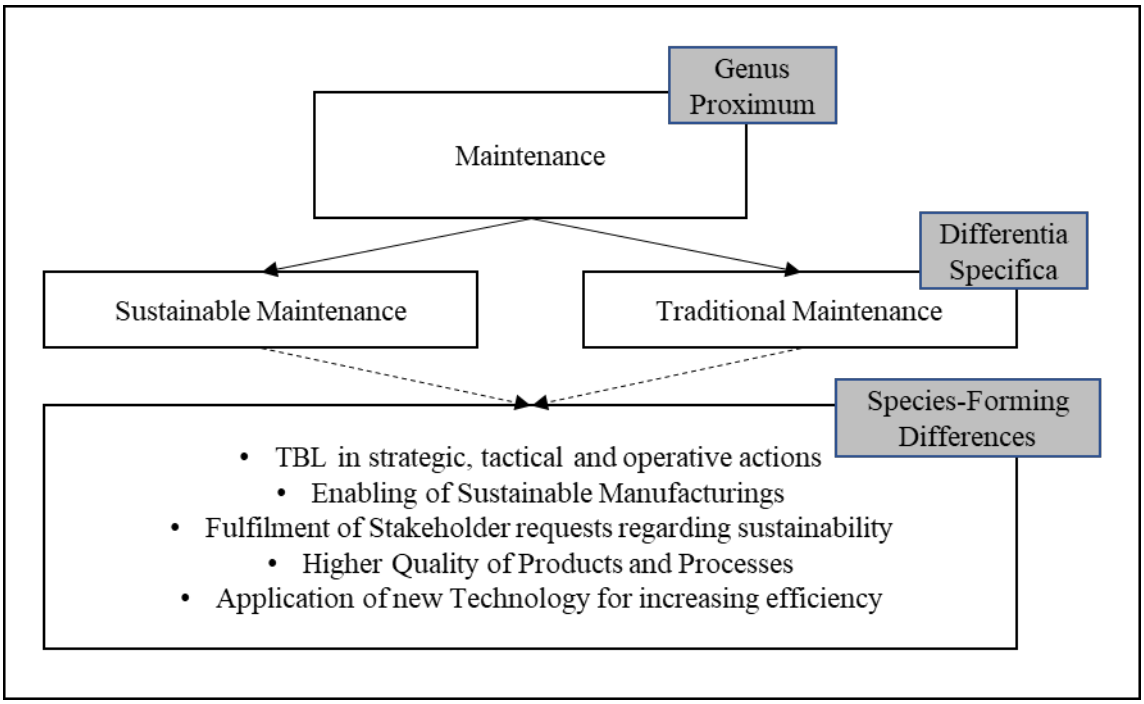

Figure 1: Genus Proximum et Differentia Specifica for Sustainable Maintenance

Thus, the definition of sustainable maintenance with the species-forming difference from traditional maintenance is as follows: Sustainable Maintenance enables the implementation of **Sustainable Manufacturing through the integrative** inclusion of the **Triple Bottom Line** in the **strategic, tactical, and operational** measures. A focus is placed on meeting **stakeholder requirements** regarding achieving **Sustainable Development.** The goals of Sustainable Maintenance include higher **quality** of the products and processes to be manufactured as well as increased **efficiency** through the application of **new technologies**.

Derived from this definition and the definitions of each keyword included, a Sustainable Maintenance Model for manufacturing companies was developed and shown in Figure 2. This model shows the possible interactions between the different keywords previously developed within a manufacturing company. In the following chapters, the keywords that were previously assigned to Sustainable Maintenance will be described based on findings in the systematic literature review. Each keyword will be described generically first and then with regard to maintenance activities.

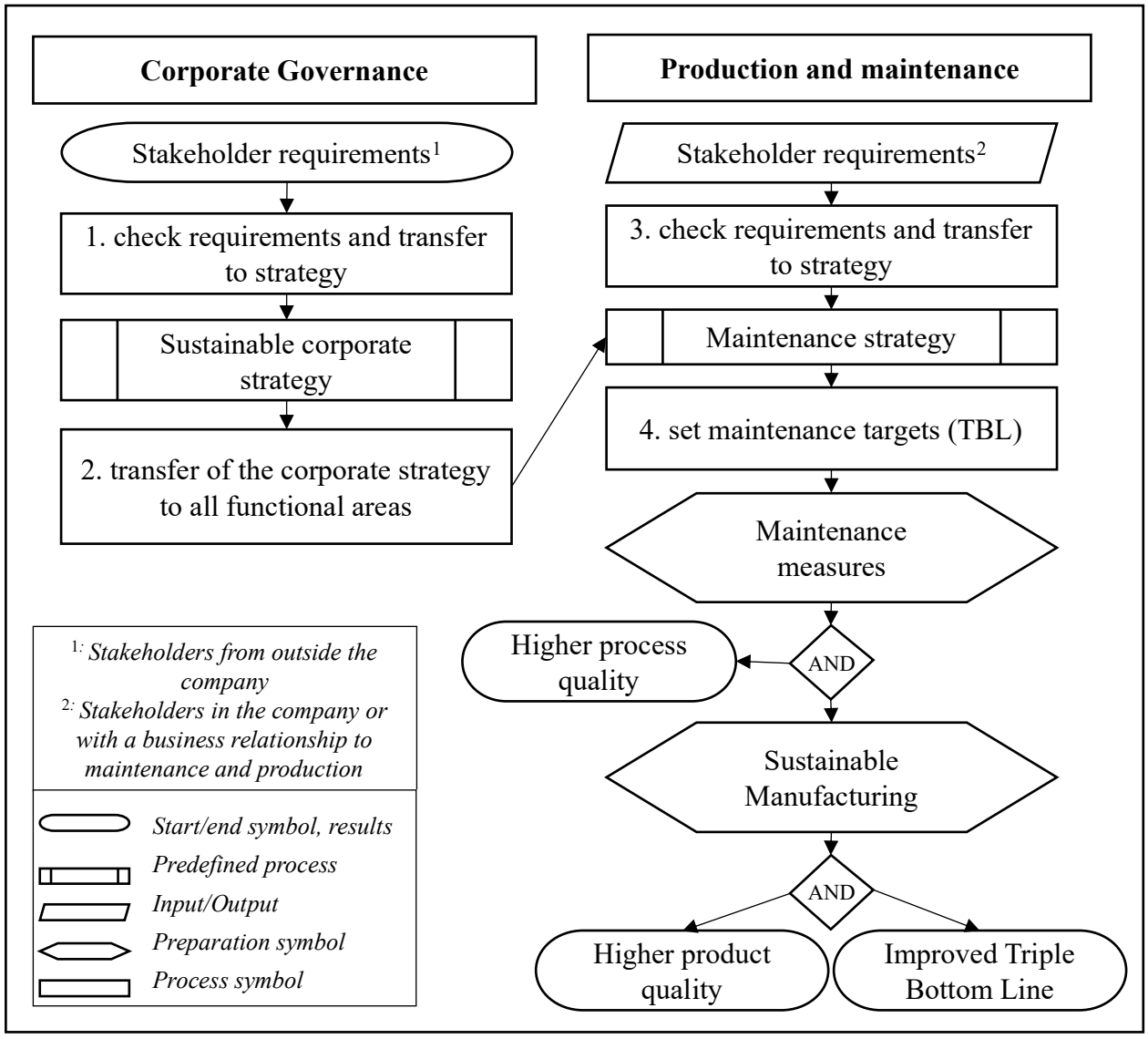

Figure 2: Sustainable Maintenance Model

3.2.1 Triple Bottom line

The Triple Bottom Line consists of three aspects: Economic, Ecological and Social [28]. The economic aspect of sustainability refers to productivity and profitability, efficiency and effective investments, the environmental aspect refers to the purchase of renewable energy, prevention of pollution and safe handling of hazardous materials, while the social aspect focuses on the health and safety of employees and good working conditions [36]. The three areas of sustainability must be considered in an integrated way, as changes in one aspect strongly influence the other two [4].

Maintenance helps to increase the economic value of a company [34] and can have an impact on all three aspects of sustainability [11]. A sustainable maintenance strategy has a great impact on reducing energy consumption, as a well-chosen maintenance strategy keeps the objects to be maintained in good condition, which contributes to energy efficiency, while digital and automated work planning in maintenance contributes to its standardization, which helps to identify the reasons for greatly increased energy consumption [37]. To integrate all three aspects of sustainability into maintenance, it is necessary to include sustainability in the maintenance strategy [10]. If sustainability aspects are not considered in maintenance, this can lead to higher repair costs, increased energy consumption and a higher number of occupational accidents [10]. Other consequences of non-executed or poorly executed maintenance include higher costs, downtime, waste, poor productivity, and product quality [18] hazardous emissions and accidents [35].

3.2.2 Stakeholder theory

Basically, there are two types of stakeholders, those with a connection to a company, for example customers, shareholders, or employees, and those that have a demand on a company, such as NGOs [38,39]. Stakeholders were originally described as a group without whose support the company could not exist, since corporate goals could not be formulated without knowledge of stakeholder demands [40]

Stakeholders of maintenance were, according to a study of [23] focused on economic factors, but rarely associate maintenance with sustainability. Possible stakeholders of maintenance that can support sustainable performance of the company are, for example, the development area of the company, as well as quality and production, where good cooperation and communication lead to a better understanding of the responsibility of the maintenance area. This can be reflected, for example, in well-maintained products that result from cooperation between maintenance personnel and the development department. [30]

3.2.3 Sustainable Manufacturing

Sustainable manufacturing is the process of manufacturing goods or services by conserving resources and using clean technologies [16] while being economically sound [41]. The overarching goal is to manufacture products that are fully recyclable and whose production process has a positive impact on the environment [42]. The entire production process from pre-manufacturing to post-use must be considered [43].

Maintenance plays an important role in enabling Sustainable Manufacturing, as it enables the company to maintain the efficiency of the production system and achieve the required quality of the products to be produced [42], is responsible for the availability and reliability as well as the safety of the equipment. [33]. Thus, the maintenance directly influences the Sustainable Manufacturing [29]. Failure to apply sustainable concepts in maintenance affects the production volume, quality, safety, and environment [5] which, as described above, form the basis of Sustainable Manufacturing.

3.2.4 Product and Process Quality

Economic, ecological, and social further development in companies can be achieved by applying management standards, such as DIN EN-ISO 9001, the quality management system [29]. Through the application of this standard, customer satisfaction can be increased by means of processes for system improvement and compliance with customer requirements [44].

Companies that integrate sustainability principles into their processes can achieve higher product and service quality, higher profits, and greater market share [10,34]. Maintenance is closely linked to production activities with the aim of producing high-quality products, and the quality of maintenance activities affects the quality of production, and thus the quality of products [33] as well as production costs and volumes, machine performance and availability [1]. Companies must become more aware that maintenance entrusts processes necessary for production processes with the least negative impact on the environment, economy, and society [30]. Product quality is an important factor for a trusting relationship with a company's stakeholders, which can be achieved through maintenance aimed at better quality without wasting resources [45].

3.2.5 New Technologies

In science, correlations between the application of new technologies and increased efficiency have been demonstrated. The implementation of automation, for example, leads to both increased product quality and improved process efficiency and customer satisfaction. These trends could be identified in particular regarding Industry 4.0. [46] Industry 4.0 is therefore seen as the key to improved productivity, enables economic growth and ensures the sustainability of manufacturing companies [47].

Sustainable maintenance cannot be achieved without considering new technologies [48]. The implementation of sustainable maintenance activities leads to an increase in production capacity and therefore an improvement in the performance of the company [5]. In addition, the competitive position of the company can be strengthened, and additional value can be added, the company may qualify for capital investment through sustainability standards [34]. Thus, new technologies are also relevant for sustainability in maintenance, especially since this business sector has a great contribution to the achievement of sustainability goals [41].

4. Conclusion

In the systematic literature review and the related content evaluation using the genus proximum, a definition of sustainable maintenance was developed based on previous publications on this topic. The differences between sustainable and traditional maintenance were elaborated upon, showing which of the characteristics of sustainable maintenance have an influence on the different areas of sustainability. Due to the focus on sustainable manufacturing in the context of sustainable maintenance, it can be stated that sustainable maintenance for achieving sustainable development is not a standalone function in the company, however, it cannot be seen as a pure support function either. It enables sustainable manufacturing in manufacturing companies and thus has a supporting function, but forms the basis for sustainable production, particularly regarding resource conservation, safety and efficiency and effectiveness. It can therefore be stated that sustainable development in companies can only be achieved through close cooperation between maintenance, production, and their stakeholders.

This work is subject to some limitations. In a systematic literature review, the incompleteness of the literature examined cannot be excluded. While the test of relevance of the studies examined was clearly defined by inclusion and exclusion criteria, it cannot be ruled out that conducting the study with two or more researchers would have yielded different results. Furthermore, the genus proximum according to Aristotle is one of many definitional theories, therefore, a different result could have possibly been obtained by using other approaches to definition as well. This work is also exclusively literature-based and therefore may not map the practical execution of maintenance. For this reason, it is recommended as future research that a study be conducted to solicit the opinions of experts in maintenance, manufacturing, and sustainability practice to test the characteristics of sustainable maintenance for feasibility and practical relevance. Additional further research should be conducted on target optimization when it comes to sustainability objectives in maintenance, as those often limit each other and tradeoffs must be made, as this paper only generically shows different parts of sustainable maintenance, but not the actual targeting of such.

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References

[1] Franciosi, C., Voisin, A., Miranda, S., Riemma, S., Iung, B., 2020. measuring maintenance impacts on sustainability of manufacturing industries: from a systematic literature review to a framework proposal. Journal of Cleaner Production 260, 121065.

[2] Sari, E., Shaharoun, A.B.M., Ma'aram, A.B., 2013. preliminary framework of sustainable maintenance performance measurement systems for automotive companies. AMR 845, 590-595.

[3] Stuchly, V., Jasiulewicz-Kaczmarek, M., 2014. maintenance in sustainable manufacturing. LogForum 10 (3), 273-284.

[4] Amrina, E., Aridharma, D., 2016. sustainable maintenance performance evaluation model for cement industry, in: 2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). 2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), Bali, Indonesia. 04.12.2016 - 07.12.2016. IEEE, pp. 350-354.

[5] Karuppiah, K., Sankaranarayanan, B., Ali, S.M., 2021. on sustainable predictive maintenance: exploration of key barriers using an integrated approach. Sustainable Production and Consumption 27, 1537-1553.

[6] Holgado, M., Macchi, M., Evans, S., 2020. exploring the impacts and contributions of maintenance function for sustainable manufacturing. International Journal of Production Research 58 (23), 7292-7310.

[7] Dolgui, A., Bernard, A., Lemoine, D., Cieminski, G. von, Romero, D. (Eds.), 2021. advances in production management systems. Springer, Cham, 737 pp.

[8] Olugu, E.U., Wong, K.Y., Chung Ee, J.Y., Mammedov, Y.D., 2022. Incorporating Sustainability and Maintenance for Performance Assessment of Offshore Oil and Gas Platforms: A Perspective. Sustainability 14 (2), 807.

[9] Sari, E., Shaharoun, A.M., Ma'aram, A., Yazid, A.M., 2015. sustainable maintenance performance measures: A pilot survey in Malaysian automotive companies. Procedia CIRP 26, 443-448.

[10] Campos, R.S. de, Simon, A.T., 2019. insertion of sustainability concepts in the maintenance strategies to achieve sustainable manufacturing. Ind. Jour. Man. & Prod. 10 (6), 1908-1931.

[11] Ibrahim, Y.M., Hami, N., Othman, S.N., 2019. INTEGRATING SUSTAINABLE MAINTENANCE INTO SUSTAINABLE MANUFACTURING PRACTICES AND ITS RELATIONSHIP WITH SUSTAINABILITY PERFORMANCE: A CONCEPTUAL FRAMEWORK. IJEEP 9 (4), 30-39.

[12] Hermann, M., Pentek, T., Otto, B., 2015. Design Principles for Industrie 4.0 Scenarios: A Literature Review.

[13] Tranfield, D., Denyer, D., Smart, P., 2003. towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. Br J Management 14 (3), 207-222.

[14] Cooper, H.M., 1988. organizing knowledge syntheses: A taxonomy of literature reviews. Knowledge in Society 1 (1), 104-126.

[15] vom Brocke, J., Simons, A., Niehaves, B., Reimer, K., Plattfaut, R., Cleven, A. RECONSTRUCTING THE GIANT: ON THE IMPORTANCE OF RIGOUR IN DOCUMENTING THE LITERATURE SEARCH PROCESS.

[16] Franciosi, C., Lambiase, A., Miranda, S., 2017. sustainable maintenance: a periodic preventive maintenance model with sustainable spare parts management. IFAC PapersOnLine 50 (1), 13692-13697.

[17] Bredebach, C., 2022. What Role Does Maintenance Play in Achieving Sustainability in Manufacturing? - A Scoping Literature Review, in: . ASME 2022 17th International Manufacturing Science and Engineering Conference. American Society of Mechanical Engineers Digital Collection.

[18] Franciosi, C., Iung, B., Miranda, S., Riemma, S., 2018. maintenance for sustainability in the Industry 4.0 context: a scoping literature review. IFAC PapersOnLine 51 (11), 903-908.

[19] Westermann, H., 2001. difference, specific, in: Ritter, J., Gründer, K., Gabriel, G. (Eds.), Historisches Wörterbuch der Philosophie. Completely revised edition of Rudolf Eisler's 'Wörterbuch der Philosophischen Begriffe'. Volume 11: U-V. Schwabe & Co. AG, Basel, pp. 314-326.

[20] Aristotle. Topics: Books I and VIII (trans. Smith).

[21] DIN 31051, 2012. Grundlagen der Instandhaltung. Beuth Verlag GmbH, Berlin, 12 pp.

[22] Amrina, E., Kamil, I., Aridharma, D., 2020. fuzzy multi criteria approach for sustainable maintenance performance evaluation in cement industry. Procedia Manufacturing 43, 674-681.

[23] Franciosi, C., Di Pasquale, V., Iannone, R., Miranda, S., 2021. multi-stakeholder perspectives on indicators for sustainable maintenance performance in production contexts: an exploratory study. JQME 27 (2), 308-330.

[24] Hami, N., Shafie, S.M., Omar, S., Ibrahim, Y.M., Abdulameer, S.S., Muhamad, M.R., 2020. a review of sustainable maintenance in the manufacturing companies. International Journal of Supply Chain Management 9 (3), 935-944.

[25] Ighravwe, D.E., Ayoola Oke, S., 2017. ranking maintenance strategies for sustainable maintenance plan in manufacturing systems using fuzzy axiomatic design principle and fuzzy-TOPSIS. JMTM 28 (7), 961-992.

[26] Jasiulewicz-Kaczmarek, M., 2018. identification of maintenance factors influencing the development of sustainable production processes - a pilot study. IOP Conf. Ser.: Mater. Sci. Eng. 400, 62014.

[27] Sénéchal, O., 2017. research directions for integrating the triple bottom line in maintenance dashboards. Journal of Cleaner Production 142, 331-342.

[28] Ramiya, S., Suresh, M., 2021. factors influencing lean-sustainable maintenance using TISM approach. Int J Syst Assur Eng Manag 12 (6), 1117-1131.

[29] Jasiulewicz-Kaczmarek, M., Żywica, P., Gola, A., 2021. fuzzy set theory driven maintenance sustainability performance assessment model: a multiple criteria approach. J Intell Manuf 32 (5), 1497-1515.

[30] Jasiulewicz-Kaczmarek, M., Antosz, K., Wyczółkowski, R., Mazurkiewicz, D., Sun, B., Qian, C., Ren, Y., 2021. Application of MICMAC, Fuzzy AHP, and Fuzzy TOPSIS for Evaluation of the Maintenance Factors Affecting Sustainable Manufacturing. Energies 14 (5), 1-30.

[31] Sénéchal, O., 2016. Maintenance decision support for sustainable performance: problems and research directions at the crossroads of health management and eco-design. IFAC PapersOnLine 49 (28), 85-90.

[32] Nezami, F.G., Yildirim, M.B., 2013. a sustainability approach for selecting maintenance strategy. International Journal of Sustainable Engineering 6 (4), 332-343.

[33] Jasiulewicz-Kaczmarek, M., Legutko, S., Kluk, P., 2020. management and production engineering review, 14 pp.

[34] Aditya, P., Diego, G., 2012. achieving sustainable development through maintenance excellence. Journal of Applied Engineering Science 10 (2), 79-84.

[35] Hami, N., Munadhil, Y., Yarmin, F.M., Shafie, S.M., Abdulameer, S.S., 2019. the Moderating Role of Sustainable Maintenance on the Relationship between Sustainable Manufacturing Practices and Social Sustainability: A Conceptual Framework. IJEAT 8 (5C), 222-228.

[36] Farsi, M., Mishra, R.K., Erkoyuncu, J.A., 2021. industry 5.0 for sustainable reliability centered maintenance. SSRN Journal.

[37] Bányai, Á., 2021. energy consumption-based maintenance policy optimization. Energies 14 (18), 5674.

[38] Hillman, A.J., Keim, G.D., 2001. shareholder value, stakeholder management, and social issues: what's the bottom line? Strategic Management Journal (22), 125-139.

[39] Roloff, J., 2008. learning from multi-stakeholder networks: issue-focused stakeholder management. J Bus Ethics 82 (1), 233-250.

[40] Freeman, R.E., 2015. strategic management. Cambridge University Press.

[41] Franciosi, C., Voisin, A., Miranda, S., Iung, B., 2020. integration of I4.0 technologies with maintenance processes: what are the effects on sustainable manufacturing? IFAC PapersOnLine 53 (3), 1-6.

[42] Vrignat, P., Kratz, F., Avila, M., 2022. sustainable manufacturing, maintenance policies, prognostics and health management: a literature review. Reliability Engineering & System Safety 218, 108140.

[43] Enyoghasi, C., Badurdeen, F., 2021. industry 4.0 for sustainable manufacturing: opportunities at the product, process, and system levels. Resources, Conservation and Recycling 166, 105362.

[44] DIN. Quality management systems: Requirements (ISO 9001:2015), 71 pp.

[45] Suresh, M., Dharunanand, R., 2021. factors influencing sustainable maintenance in manufacturing industries. JQME.

[46] Fettermann, D.C., Cavalcante, C.G.S., Almeida, T.D. de, Tortorella, G.L., 2018. how does industry 4.0 contribute to operations management? Journal of Industrial and Production Engineering 35 (4), 255-268.

[47] Rosin, F., Forget, P., Lamouri, S., Pellerin, R., 2020. impacts of industry 4.0 technologies on lean principles. International Journal of Production Research 58 (6), 1644-1661.

[48] Jasiulewicz-Kaczmarek, M., Gola, A., 2019. maintenance 4.0 technologies for sustainable manufacturing - an overview. IFAC PapersOnLine 52 (10), 91-96 .

Biography

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