

# A review of predominantly used maintenance approaches for construction-related factory buildings

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## **Abstract**

*Maintenance in factory buildings is becoming increasingly important as factories use it as a profit-generating tool. Literature suggests that problems such as poor maintenance budget planning, lack of communication, lack of emergency response, and lack of skilled labour are associated with selecting the predominant maintenance approach for the construction-related factory building. As a result, these problems are prevalent in developing and developed countries, including South Africa. This study aims to identify the most predominantly used maintenance approach for construction-related factory buildings in the construction industry. The paper is based on previous literature on the maintenance of construction-related factory buildings and implementing a suitable maintenance approach. The literature review focused on both the internal and South African contexts. The study revealed that preventive, corrective, and predictive maintenance analyses were the most commonly used maintenance approaches in the sample literature. This paper contributes to a better understanding of maintenance management and the aspects that impact the practical use of the maintenance approach for construction-related factory buildings.*

**Keywords:** Maintenance, Maintenance Approaches, Maintenance Management.

## **1. INTRODUCTION**

South Africa is one of many countries on the African continent that face challenges with maintaining factory buildings. As a result, these buildings deteriorate and get damaged without being attended to when needed (Dzulkifli et al., 2021). In addition, Simpeh (2013) highlighted a prevalent disregard for building maintenance in South Africa. Hence, regular maintenance is necessary to preserve the factory building's appearance and functionality. According to Thoben, Wiesner and Wuest (2017), global manufacturing sites and factory buildings are undergoing a fourth industrial revolution, enabling intelligent factories with vertically and horizontally integrated manufacturing systems. Pieczara (2020) indicated that architectures face unique challenges when designing industrial factories due to their high complexity, which will make maintenance quite difficult to execute because of the design of the building. Nonetheless, Zhou A. et al. (2009) highlighted that the factory building layout should meet the needs of employees with sufficient workspace, amenities, and office space. Furthermore, it should comply with legal and occupational safety regulations and integrate with a client area, Pieczara

(2020).

Multiple authors have highlighted various definitions of factory building in literature to provide a better understanding of the term. According to Rojí, Losada, and Cuadrado (2007), the term 'factory' often refers to the general elements of industrial manufacturing rather than just industrial buildings. However, both concepts share the presence of construction structures designed by architects using natural and artificial materials and building methods. These structures are built within a regulated environment to ensure consistent quality and safety standards. Cuadrado et al. (2016) define a factory building as a location for industrial manufacturing and storage activities. Biggs (1995) defines factory buildings from two perspectives: either as a vehicle for industrial transformation or as a dynamic component of the manufacturing process. Vaishnavi (2023) explains factory buildings as the primary tool for production, accommodating all other production tools and mechanisms.

According to Cuadrado et al. (2016), it is essential to consider the financial requirements for maintaining and preserving a factory building throughout its useful life. Hence, a well-executed and compelling maintenance approach for construction-related factory buildings is essential. Previous literature indicated that factory buildings degrade slowly over time for various reasons, such as unattended damages, neglected defects, and natural causes (Dzul kifli et al., 2021). As a result, no preventive, predictive, or corrective maintenance was executed. Similarly, Cooke (2003), as well as Sander and Wang (2000), discussed the effective use of a factory building, and everything attached to it depends on the ability of the company to implement an efficient maintenance approach. This study aims to identify the most predominantly used maintenance approach for construction-related factory buildings. The following sections of the paper provide a detailed description of the methodology used to conduct this study. The results of the study are presented in the subsequent sections, along with the implications that can be inferred from them.

## **2. RESEARCH METHODOLOGY**

The study intended to determine the most used maintenance approach for construction-related factory buildings. The paper is part of an overall study for a master's degree research. As a result, the results of a literature review regarding the maintenance approaches are provided. The paper only considered peer-reviewed conference papers and journals. The Scopus search engine was used to find relevant publications. Considering the global context, the keywords used were 'maintenance', 'maintenance approaches', and 'maintenance management'. Initially, 1056 documents were found, but a more extensive search was conducted, limiting the document type to journal articles and conference papers, the subject area was limited to engineering, and the language to English. Additionally, the search was restricted to conference papers and journal articles published between the year 2000 and 2024, resulting in a total of 264 research papers. However, it was not viable to include all the papers.

Therefore, the studies were carefully reviewed based on the relevant literature, publications, and their applicability to the South African construction industry. As a result, 78 publications were deemed suitable for further analysis. The subsequent section of the study focused on reviewing and presenting the articles, as well as discussing the most commonly used maintenance approaches. The findings were used to make recommendations and to draw the conclusion.

### **3. FINDINGS ON PREDOMINANTLY USED MAINTENANCE APPROACHES FOR CONSTRUCTION RELATED FACTORY BUILDING.**

The 78 publications considered for this study were reviewed, the conclusions from each paper were compiled, and nine predominant maintenance approaches were found; numbers denote the papers in Table 1 with the corresponding authors. Fredrickson and Larsson (2012) and Ndjenja and Visser (2015) have recognised specific maintenance approaches as reliable for maintaining construction-related factory buildings, regardless of the methodology selected. Muyengwa and Marowa (2015) mentioned that preventive and predictive maintenance are two proactive approaches currently replacing the outdated maintenance approaches used by most factories. At the same time, Swanson (2001) noted that Total Productive Maintenance (TPM) is a destructive maintenance approach that is primarily utilised in factory buildings and (Ndjenja and Visser, 2015) mentioned that Reliability Centred Maintenance (RCM) and Business Centred Maintenance (BCM) are well-documented maintenance approaches preferably used in factory buildings for ensuring that maintenance activities are carried out effectively and efficiently. The findings of this study demonstrated crucial approaches that influence maintenance management implementation and adaptation. Table 1 summarizes the identified methodologies from the sampled literature. As stated in Table 1, the predominantly used approaches were preventive, corrective, predictive, and condition-based maintenance. A detailed review of some of the predominant maintenance approaches is discussed below.

#### **3.1 Reliability Centred Maintenance (RCM)**

Muyengwa and Morwa (2015) define reliability-centred maintenance as a systematic qualitative maintenance approach that organises maintenance within the facility. Whereas (Bertling 2002, Gupta and Mishra 2016, Backlund 2003, and Ndjenja and Visser 2015) define RCM as a maintenance process for ensuring that a physical asset continues to meet the users' needs in its current operational context. According to Ndjenja and Visser (2015) and Kobbacy et al (2008); the RCM approach was created for the aircraft industry and afterwards applied to several other sectors, such as the construction industry and military branches, indicating that it has been used successfully for over 20 years. Kobbacy et al (2008); and Pun et al. (2002) highlighted that RCM's primary purpose is to reduce maintenance costs by focusing on the most critical system operations and eliminating or

minimising non-essential maintenance procedures. Moreover, Campbell and Reyes-Picknell's (2016) RCM establishes a universal language that all employees in the factory building may utilize to communicate efficiently throughout their business affairs. Hence, Ghazinoory, Abdi and Mehr (2011) emphasised that RCM is not a replacement for poor design, construction quality, or maintenance procedures.

### **3.2 Total Productive Maintenance (TPM)**

According to Chan, Lau, Chan, and King (2003), TPM is a maintenance relationship between the production and maintenance departments that works synergistically between all organizational functions. Venkatesh (2005), Cua et al (2001) and Muyengwa and Morwa (2015) define TPM as a maintenance program that uses a newly defined idea to maintain buildings and equipment to optimise productivity. According to Rajput and Jayaswal (2012) and Mungani and Visser (2013), the efficiency of manufacturing factory buildings is essential for desired productivity, cost, inventory, quality, and delivery. Gupta et al (2006) and Ndjenja and Visser (2015), TPM aims to make existing assets more useful while decreasing the need for additional capital expenditures because investment in human resources can also lead to increased product quality, greater hardware utilisation, and lower labour expenses. According to Rajput and Jayaswal (2012) and Mungani and Visser (2013), TPM aims to cultivate skilled maintenance personnel and implement a no-defect, no-loss, and no-failure maintenance management strategy. Gupta, Tewari, and Sharma (2006) state that implementing a TPM system is one method for enhancing the performance of maintenance activities in factory buildings. Ahuja and Khamba (2008) state that TPM's implementation approach optimises asset effectiveness, eliminates breakdowns, and promotes autonomous maintenance.

### **3.3 Corrective Maintenance (CM)**

According to Mydin (2015), the most straightforward maintenance approach on factory buildings is Corrective Maintenance, which involves using a building component until it malfunctions. Eugen, (2011), Garg and Deshmukh (2006). CM includes all actions, such as replacing or repairing an element that has failed to the point that it can no longer serve its intended purpose. Furthermore, Corrective Maintenance can be expensive due to potential damage to other components. For instance, failure of the roof can cause damage to the ceiling and interior part of the building, Mydin (2015); Horner, Haram and Munns (1997). In addition, Horner et al. (1997) indicated that failure of an item might occur at an inconvenient time for both the user and the maintaining authority; therefore, Lateef et al. (2010), this can make organizing labour in the maintenance department and replacement parts extremely difficult and will result in high costs.

### **3.4 Preventive Maintenance (PM)**

According to Au-Yong, Ali, and Ahmad (2014), one of the most significant issues in the construction sector is poor maintenance of buildings, which affects factory buildings. Carpio and Prieto (2021), naturally, structures and their parts deteriorate over time, gradually losing functionality until they can no longer meet the demands and requirements of users. Cruzan (2020) defines Preventive Maintenance as a proactive maintenance approach which entails all the duties maintenance staff members carry out to keep structures or buildings in good shape, and these duties include Oiling or greasing bearings, Painting walls, and repairing the factory buildings such as roofing. Garg and Deshmukh (2006) define Preventive Maintenance as a set of operations performed at regular intervals based on time, production, and machine condition to extend asset life or detect significant wear. Kyriakidis and Dimitrakos (2006), Horner, Haram and Munns (1997) Preventive Maintenance (PM) was developed to alleviate the shortcomings of Corrective Maintenance by minimising the chance of failure and avoiding unanticipated breakdowns. Also, Au-Yong et al. (2014) and Chinese and Ghirardo (2010) emphasised that the primary driver of existing unsatisfactory maintenance performance is the absence of preventive actions.

### **3.5 Predictive Maintenance (PdM)**

According to Tshabuse (2015), Predictive Maintenance is the approach that considers the status of the maintained item and uses preventive measures to plan maintenance actions to avoid failure. Ahuja and Khamba (2008), Pintelon and Parodi-Herz (2008) Predictive Maintenance is also known as Condition-Based Maintenance (CBM), and it is started in response to a specific item issue or degradation in performance. Tse (2002), Mungani and Visser (2013), this strategy is usually used when the equipment/ item detects some physical problems such as corrosion, vibrations, etc., which may lead to deterioration, then Predictive Maintenance will occur. Mobley (2002), Pun et al. (2002), and Tsang et al. (2002) state that although Predictive Maintenance costs more, it boosts and enhances manufacturing and production factories' efficiency, product quality, and overall effectiveness.

### **3.6 Condition-Based Maintenance (CBM)**

According to Mungani and Visser (2013) Condition-Based Maintenance involves continuous monitoring and routine inspection of an item or component to minimize the total cost of repairs due to the knowledge of its significant deterioration. Thoben et al. (2017) posit that this maintenance approach intends to decrease overall maintenance costs by collecting condition data on building systems, particularly crucial elements of the building. Even so, according to Prajapati et al. (2012) and Muyengwa and Morwa (2015), the maintenance approach may not be suitable for all building systems or assets due to the availability of maintenance technology and cost-effectiveness. Hence, Ahuja and

Khamba (2008) and Carpio and Prieto (2021) stated that maintenance has long been a costly and challenging aspect of supporting a system's product lifecycle.

#### 4. MAINTENANCE MANAGEMENT

Maintenance management must diversify physical assets and implement new approaches for better planning, organising, and resource control to achieve productivity, quality, safety, health, and environmental goals. According to Garg and Deshmukh (2006), The importance of maintenance management has increased over time. Hence, Mohd Noor et al. (2021) stated that maintenance management plays a significant role in construction-related factory profitability. Thus, Muyengwa and Morwa (2015) noted that maintenance management must coordinate all business activities in the factory buildings. Hence, Crespo (2009) divided the maintenance management process into two processes: the strategy's definition and the strategy's implementation. Furthermore, Mohd Noor et al. (2021) highlighted that maintenance management involves planning, coordinating, and overseeing maintenance tasks to ensure the factory's smooth operation while improving its overall structure and economic elements. Moreover, Mfody and Weinert (2020) stated that it is crucial to understand the functions and requirements for a Computerised Maintenance Management System (CMMS) to implement the IR4.0 concept, as most of its needs and ideas can currently be met by CMMS.

Table 1: Maintenance Approaches

Maintenance approaches	References	Total	Rank
PM	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20	20	1st
CM	21,22,28,29,30,31,32,33,34,35,36,37,38, 39,40,41,42	17	2 <sup>nd</sup>
PdM	11,24,25,43,44,45,46,47,48,49,50,51	12	3 <sup>rd</sup>
CBM	27,52,53,54,55,57,59,60,61,62	10	4th
RCM	56,58,63,64,65,66,67	7	5th
TPM	68,69,70,71,72	5	5th
BCM	26,73,74,75	4	6 <sup>th</sup>
TQMain	27,76,77	3	7 <sup>th</sup>
ECM	78;24	2	9 <sup>th</sup>

**References:** 1=A1-Najjar and Alsyouf (2003); 2= Charles et al (2003); 3=Mungani and Visser (2013); 4=Thoben et al. (2017); 5=Bris et al (2003) 6=Tse (2002); 7=Au-yong et al. (2014) ; 8= Gang and Deshmukh (2006); 9=Carpio and Prieto (2021); 10=Kyriakidis and Dimitrakos (2006); 11= Chinese and Ghirardo (2010); 12=Pun et al. (2002); 13=Zuraidi, Akasah and Rahman (2011); 14=Bloch-Mercier (2002); 15=Au-Yong, Ali, and Ahmad(2015); 16=Aksa et al., (2021) ;17= Chau, Zubbir, Ali and Au-Yong(2018) ; 18= Chen et al (2003);19= Yildizhan (2006);20=Zubbir, Ali and Au-Yong (2016) ; 21=Tshabuse (2015); 22= Carnero(2006); 23= Mobley (2002);24= Wang and Christer (2000); 25= Sidhu et al (2023);26=Tse (2006); 27= El-ferik and Ben-daya, (2010); 28=Aksa et al, (20201); 29:Deighton(2016); 30=Dhillon (2002); 31= Munyegwa and Morwa (2015); 32=Aronson (2002); 33=Ahuja and Khamba (2008); 34=Dzuilkifli et al. (2021); 35= Mydin(2015); 36= Eugen

(2011);37= Rajput and Jayaswal (2012); 38=Cruzan (2020); 39= Lateef et al (2010); 40; Crespo et al (2009); 41=Ighravwe and Oke (2019); 42= Shen and Yan (2013); 43; Bandi et al(2003). 44= Pintelon and Parodi-Herz (2008); 45=Carnero (2006); 46=Mobley(2002); Mobley (2008); 47=Pinjala and Pintelon(2006);48= Spendla et al. (2017); 49=Mobley (2011); 50=Katona and Panfilov (2018); 51=Klees and Evirgen(2022); 52= Chris and Wang (2001); 53=Ling et al (2006); 54=Mahdi et al (2010); 55= Sherwin (2000); 57= Prajapati et al (2012); 59=Chen and Trivedi(2002); 60=Chen and Trivedi(2005); 61= Lu et al(2007); 62=Yam et al (2001); 56= Peng (2016); 58=Ghazinoory, Abdi and Mehr (2011); 63=Bertling (2002); 64= Kobbacy et al (2008); 65=Deshpande and Modak (2002); 66=Gupta and Mishra (2016); 67=Oseghale,(2014); 68=Singh et al (2016); 69=Chan (2005); 70=Chan et al (2003); 71= Cua et al (2001);72= Ndjenja and Visser (2015); 73= Waeyenbergh and Pintelon (2002); 74= Gupta et al (2006); 75=Kelly (2007); 76=Seth and Tripathi (2006); 77=Eti, Ogaji and Probert (2006); 78=Tsang (2002)

## 5. CONCLUSION

According to current literature, this paper examined and assessed the various maintenance approaches for construction-related factory buildings. If these approaches are implemented by the maintenance personnel in the construction-related factories, the building structure can be preserved, have a longer lifespan, remain in good condition, and avoid deterioration. Maintenance management also emphasises the importance of ensuring that factory buildings are maintained to the required standards, necessitating maintenance policies and guidelines. Meeting the necessary maintenance standards can enhance the overall productivity and profitability of the factory, as it ensures that the business operates smoothly. However, since this study is solely a literature analysis, its conclusions are not exhaustive, and further investigation, including the use of primary data, is needed to identify the most appropriate maintenance approach for construction-related factory buildings.

## 6. REFERENCES

- Ahuja, IPS and Khamba, JS., 2008. 'Total productive maintenance: literature review and directions', *International Journal of Quality & Reliability Management*, 25(7), pp. 709–756.
- Aksa, K., Aitouche, S., Bentoumi, H. and Sersa, I., 2021. Developing a web platform for the management of the predictive maintenance in smart factories. *Wireless Personal Communications*, 119(2), pp.1469-1497.
- Al-Najjar, B. and Alsyouf, I., 2003. "Selecting the most efficient maintenance approach using fuzzy multiple criteria decision making", *International Journal of Production Economics*, 1, pp. 85-100.
- Amik Garg, S.G. Deshmukh., 2006. "Maintenance management: literature review and directions", *Journal of Quality in Maintenance Engineering*, 12( 3), pp. 205 - 238
- Aronson, B.R. (2002), "What to measure for proper maintenance", *Manufacturing Engineering*, 129(4) pp. 71-6.

- Au-Yong, CP, Ali, AS and Ahmad, F., 2014. 'Improving occupants' satisfaction with effective maintenance management of HVAC system in office buildings, *Automation in Construction*, 43, pp. 31–37.
- Au-Yong, C.P., Ali, A.S. and Ahmad, F., 2014. 'Preventive Maintenance Characteristics towards Optimal Maintenance Performance': A Case Study of Office Buildings. *World Journal of Engineering and Technology*, 2, 1-6.
- Au-Yong, CP, Ali, AS & Ahmad, F., 2015, 'Participative Mechanisms to Improve Office Maintenance Performance and Customer Satisfaction', *Journal of Performance of Constructed Facilities*, 29(4), p. 04014103.
- Bandi, R.K., Vaishnavi, V.K. and Turk, D.E., 2003. "Predicting maintenance performance using object-oriented design-oriented metrics", *IEEE Transactions on Software Engineering*, (29) 1, pp. 77-87.
- Bertling, L., 2002. Reliability centred maintenance for electric power distribution systems. Ph.D. Thesis, KTH, Stockholm, Sweden.
- Bloch-Mercier, S., 2002. "A preventive maintenance policy with sequential checking procedure for a Markov deteriorating system", *European Journal of Operational Research*, 142 (3), pp. 548-76.
- Bris, R., Chatelet, E. and Yalaoui, F. (2003), "New method to minimize the preventive maintenance cost of series parallel systems", *Reliability Engineering and Systems Safety*, 82 (3), pp. 247-55.
- Carnero, M.C. (2006), "An evaluation system of the setting up of predictive maintenance programmes", *Reliability Engineering & System Safety*, 91(1), pp. 945-963.
- Carpio, M and Prieto, AJ., 2021. 'Expert Panel, Preventive Maintenance of Heritage Buildings and Fuzzy Logic System: An Application in Valdivia, Chile', *Sustainability*, 13(12), p. 6922.
- Cua, KO, McKone, KE & Schroeder, RG., 2001, 'Relationships between implementation of TQM, JIT, and TPM and manufacturing performance', *Journal of Operations Management*, 19(6), pp. 675–694.
- Charles, A., Floru, I., Azzaro-Pantel, C., Pibouleau, L. and Domenech, S., 2003. "Optimization of preventive maintenance strategies in a multipurpose batch plant: application to semiconductor manufacturing", *Computers & Chemical Engineering*, 27(4), pp. 449-67.
- Chan, FTS, Lau, HCW, Ip, RWL, Chan, HK & Kong, S., 2005. 'Implementation of total productive maintenance: A case study', *International Journal of Production Economics*, 95(1), pp. 71–94.
- Chua, S.J.L., Zubbir, N.B., Ali, A.S. and Au-Yong, C.P., 2018. Maintenance of high-rise residential buildings. *International journal of building pathology and adaptation*, 36(2), pp.137-151.
- Chen, C., Chen, Y. and Yuan, J. 2003, "On a dynamic preventive maintenance policy for a system under inspection", *Reliability Engineering and System Safety*, 80(1), pp. 41-7.
- Chen, D. and Trivedi, K.S., 2002. "Closed form analytic results for condition-based maintenance", *Journal of Reliability Engineering and System Safety*, 76, pp. 43-51.
- Chen, D. and Trivedi, K.S., 2005. "Optimization for condition-based maintenance with semi-Markov decision process", *Reliability Engineering and System Safety*, 90(1), pp. 25-9

- Chinese, D and Ghirardo, G., 2010. 'Maintenance management in Italian manufacturing firms', *Journal of Quality in Maintenance Engineering*, 16(2), pp. 156–180.
- Chris, K.M. and Wang, Z., 2001. "Using fuzzy linguistics to select optimum & condition based strategies", *International Journal of Mechanical Systems & Signal Processing*, 15 (6), pp. 1129-1140.
- Cuadrado, J, Zubizarreta, M, Rojí, E, Larrauri, M and Álvarez, I., 2016. 'Sustainability assessment methodology for industrial buildings: three case studies', *Civil Engineering and Environmental Systems*, 33(2), pp. 106–124.
- Crespo Márquez, A.; Moreu de León, P.; Gómez Fernández, J.F.; Parra Márquez, C.; López Campos, M., 2009. *The maintenance management framework*. *Journal of Quality in Maintenance Engineering*, 15(2), pp. 167–178.
- Cruzan, R., 2020. *Manager's guide to preventive building maintenance*, River publishers.
- Deighton, M., 2016. 'Facility integrity management: effective principles and practices for the oil, gas and petrochemical industries. Gulf Professional Publishing'.
- Deshpande, V.S. and Modak, J.P., 2002. Application of RCM to a medium scale industry. *Reliability Engineering & System Safety*, 77(1), pp.31-43.
- Dhillon, B.S., 2002, *Engineering Maintenance: A Modern Approach*, CRC Press, Boca Raton, FL
- Dzulkifli, N, Sarbini, NN, Ibrahim, IS, Abidin, NI, Yahaya, FM and Nik Azizan, NZ., 2021. 'Review on maintenance issues toward building maintenance management best practices', *Journal of Building Engineering*, 44, p. 102985.
- El-Ferik, S and Ben-Daya, M., 2010. 'Integrated Production Maintenance Model Under Imperfect Age-Based Maintenance Policy And Non-Negligible Maintenance Times', *Asia-Pacific Journal of Operational Research*, 27(04), pp. 539–558.
- Eugen P., 2011. 'How To Choose the Best Maintenance Strategy For A Company', DOAJ (DOAJ: Directory of Open Access Journals).
- Eti, M.C., Ogaji, S.O.T. and Probert, S.D., 2006. "Strategic maintenance management in Nigerian Industries", *Journal on Applied Energy*, 83(3), pp. 211-227.
- Margaritopoulos, E. and Xenidis, Y., 2023. Condition-based Maintenance Using BIM: A Case Study of Energy Modeling for a Residential Building. *Journal of Engineering, Project & Production Management*, 13(3).
- Ghazinoory, S., Abdi, M. and Azadegan-Mehr, M., 2011. 'SWOT methodology: a state-of-the-art review for the past, a framework for the future'. *Journal of business economics and management*, 12(1), pp.24-48.
- Gupta, G. and Mishra, R.P., 2016. "A SWOT analysis of reliability centered maintenance framework". *Journal of Quality in Maintenance Engineering*, 22(2), pp.130-145.
- Gupta, S., Tewari, P.C. and Sharma, A.K., 2006. TPM concept and implementation approach. *Maintenance World*, 21, pp.1-18.

- Ighravwe, DE and Oke, SA., 2019. 'A multi-criteria decision-making framework for selecting a suitable maintenance strategy for public buildings using sustainability criteria', *Journal of Building Engineering*, 24, p. 100753.
- Kobbacy, K.A., Murthy, D.P., Rausand, M. and Vatn, J., 2008. Reliability centred maintenance. *Complex system maintenance handbook*, pp.79-108.
- Katona, Attila and Panfilov, Peter., 2018. Building Predictive Maintenance Framework for Smart Environment Application Systems, Proceedings of the 29th DAAAM International Symposium, Published by DAAAM International, ISBN 978-3-902734-xx-x, ISSN 1726-9679, Vienna, Austria
- Kelly, A., 2007, *Strategic maintenance planning*, Butterworth-Heinemann, Elsevier, Oxford.
- Klees, M and Evirgen, S., 2022. 'Building a smart database for predictive maintenance in already implemented manufacturing systems', *Procedia Computer Science*, 204, pp. 14–21.
- Kyriakidis, EG and Dimitrakos, TD., 2006. 'Optimal preventive maintenance of a production system with an intermediate buffer', *European Journal of Operational Research*, 168(1), pp. 86–99.
- Lateef, OA, Khamidi, MF and Idrus, A., 2010. 'Building Maintenance Management in a Malaysian University Campus: A Case Study', *Australasian Journal of Construction Economics and Building*, 10(1/2), p.76
- Ling, W., Jian, C. and Jun, W., 2006. "Selection of optimum maintenance strategies based on a fuzzy analytic hierarchy process", *International Journal of Production Economics*, 107(1), pp. 151-163.
- Lu, S., Tu, Y.C. and Lu, H. (2007), "Predictive condition-based maintenance for continuously deteriorating system", *Quality and Reliability Engineering International*, 23 (1), pp. 71-81
- Mahdi, B., Hossein, B. and Taha, H.H., 2010. "Selecting optimum maintenance strategy by fuzzy interactive linear assignment method", *Applied Mathematical Modelling*, 35(1), pp. 152-164.
- Mobley, R.K., 2002. *An Introduction to Predictive Maintenance*, Butterworth-Heinemann, Elsevier, New York, NY.
- Mobley, R.K., 2008. *Total productive maintenance*. Mobley RK, *Maintenance Engineering Handbook*, 7th Edition, McGraw Hill Companies Inc., USA.
- Mobley, R.K 2011, *Maintenance Fundamentals*, Elsevier.
- Mohd Noor, H, Mazlan, SA and Amrin, A 2021, 'Computerized Maintenance Management System in IR4.0 Adaptation - A State of Implementation Review and Perspective', *IOP Conference Series: Materials Science and Engineering*, 1051(1), p. 012019.
- Młody M and Weinert A (2020) *Industry 4.0 in Poland: A Systematic Literature Review and Future Research Directions* pp 43-71
- Mungani, DS and Visser, JK., 2013. 'Maintenance Approaches for Different Production Methods', *The South African Journal of Industrial Engineering*, 24( 3).
- Muyengwa, G and Marowa, Y., 2015. 'Analysing adoption of maintenance strategies in manufacturing companies', University of Johannesburg: Department of Mechanical & Industrial Engineering Technology.

- Ndjenja, L and Visser, JK., 2015. 'Development of a Maintenance Strategy for Power Generation Plants', *SAIEE Africa Research Journal*, 106(3), pp. 132–140.
- Oseghale, G.E., 2014, Impact of Maintenance Strategies on the Performance of Industrial Facilities In Selected Industrial Estates In Lagos State, Nigeria, *American Journal of Engineering Research (AJER)*,03(08), p.171-179
- Othuman Mydin 2015, 'Performance Measurement of Building Maintenance Practice', *SSRN Electronic Journal*, RELX Group (Netherlands).
- Peng, H. and van Houtum, G.J., 2016. Joint optimization of condition-based maintenance and production lot-sizing. *European Journal of Operational Research*, 253(1), pp.94-107.
- Pinjala, K.S., Pintelon, L. and Verreecke, A., 2006. "An empirical investigation on the relationship between business and maintenance strategies", *International Journal of Production Economics*, 104 (1), pp. 214-229.
- Pintelon, L.M. and Parodi-Herz, A., 2008. "Maintenance: an evolutionary perspective", *Complex System Maintenance Handbook*, (Series in Reliability Engineering), Springer-Verlag, London.
- Pun, K, Chin, K, Chow, M and Lau, HCW 2002, 'An effectiveness-centred approach to maintenance management', *Journal of Quality in Maintenance Engineering*,8(4), pp. 346–368.
- Prajapati, A, Bechtel, J and Ganesan, S., 2012. 'Condition based maintenance: a survey', *Journal of Quality in Maintenance Engineering*,18(4), pp. 384–400.
- Rajput, H.S. and Jayaswal, P., 2012. A total productive maintenance (TPM) approach to improve overall equipment efficiency. *International Journal of Modern Engineering Research*, 2(6), pp.4383-4386.
- Seth, D. and Tripathi, D., 2006. "A critical study of TQM and TPM approaches on business performance of Indian manufacturing industry", *Total Quality Management Journal*,17(7), pp. 811-824
- Shen Xueqiang and Bai Yan., 2013. 'Selection of Optimum Maintenance Strategy Based On Intuitionistic Fuzzy Interpretations of Multi-Criteria Group Decision Making Method', *International Journal of Digital Content Technology and its Applications*, 7(7), pp. 1024–1031.
- Sherwin, D., 2000. "A review of overall models for maintenance management", *Journal of Quality in Maintenance Engineering*, 6(3), pp. 138-164.
- Sidhu, S.S., Singh, K. and Ahuja, I.P.S., 2023. Analysis of the impact of different maintenance practices on business performance of SMEs using structural equation modeling. *International Journal of Business Excellence*, 20, pp.1756-0055.
- Singh, R.K., Gupta, A., Kumar, A. and Khan, T.A., 2016. Ranking of barriers for effective maintenance by using TOPSIS approach. *Journal of Quality in Maintenance Engineering*, 22(1), pp.18-34.
- Spendla, L, Kebisek, M, Tanuska, P and Hrcka, L, 2017, Concept of predictive maintenance of production systems in accordance with industry 4.0, *IEEE Xplore*, pp. 000405–000410.

Thoben, K-D, Wiesner, S & Wuest, T., 2017. "Industrie 4.0" and Smart Manufacturing – A Review of Research Issues and Application Examples', *International Journal of Automation Technology*, 11(1), pp. 4–16.

Tsang, AHC 2002, 'Strategic dimensions of maintenance management', *Journal of Quality in Maintenance Engineering*, 8(1), pp. 7–39.

Tse, PW., 2002. 'Maintenance practices in Hong Kong and the use of the intelligent scheduler', *Journal of Quality in Maintenance Engineering*, 8(4), pp. 369–380.

Tshabuse, F., 2015. *Applying preventive and predictive maintenance best practice on plant maintenance*. University of Johannesburg (South Africa).

Waeyenbergh, G. and Pintelon, L. (2002), "A framework for maintenance concept development", *International Journal of Production Economics*, 77(3), pp. 299-313.

Wang, W. and Christer, A.H., 2000. Towards a general condition-based maintenance model for a stochastic dynamic system. *Journal of the operational research society*, 51(2), pp.145-155.

Weber, A. and Thomas, R. 2006. 'Key Performance Indicators, Measuring and Managing the Maintenance Function', Ivira Corporation, Ontario.

Yam, RCM, Tse, PW, Li, L and Tu, P 2001, 'Intelligent Predictive Decision Support System for Condition-Based Maintenance', *The International Journal of Advanced Manufacturing Technology*, 17(5), pp. 383–391.

Zuraidi, S.N.F., Akasah, Z.A. and Rahman, M.A.A., 2011. Civil engineering and architectural building features disparity and preservation of structural and fabrics integrity in heritage building: A Review. *Sustainable Building and Infrastructure Systems: Our Future Today*, p.82.