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STRATEGIES TO SUCCESSFULLY IMPLEMENT INDUSTRY 4.0 CONCEPT FOR PREDICTIVE MAINTENANCE IN FACILITIES MANAGEMENT

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Abstract: Maintenance management is an important function in Facilities Management (FM). Industries moved to preventive maintenance to counteract the inefficiencies of reactive maintenance, and further evolved into predictive maintenance (PdM). The demand for Industry 4.0-enabled PdM for FM has risen as a result of the industrial revolution and the dynamic nature of the FM industry. There are technology, investment, data, employees, integration, standardization, communication and security-related challenges in applying the Industry 4.0 concept for carrying out effective PdM under FM, which needs proper solutions. Thus, the study aimed at identifying strategies to successfully implement the Industry 4.0 concept for effective PdM in FM. The qualitative research approach was undertaken to accomplish the aim. A comprehensive literature review followed by 15 semi-structured interviews was carried out with experts in the maintenance sector who have Industry 4.0 knowledge. The data was collected from experts in Australia, Qatar, Dubai, Singapore, and Sri Lanka, and analyzed through code-based content analysis using NVivo 12. The research identified strategies to overcome technology, investment, data, employees, integration, standardization, communication and security-related challenges faced by facilities managers in applying the Industry 4.0 concept for carrying out PdM. Integrating Industry 4.0 along with PdM could be a game-changer for maintenance practitioners in the FM sector, allowing them to implement a real-time and failure-free maintenance approach that improves overall maintenance effectiveness and retains them ahead of the competition.

Keywords: *Industry 4.0, Facilities Management (FM), Predictive Maintenance (PdM), Challenges, Strategies.*

1. Introduction

Facilities Management (FM) is an integrated approach, which is used to manage and maintain facilities in an organization (Barrett & Baldry, 2009). FM functions span several aspects such as business continuity, finance and business, environmental stewardship and sustainability, human factor, project management, quality, communication, operation and maintenance, property management, real estate, emergency preparedness, leadership and strategy, and technology (Nafrizon et al., 2020). However, the authors highlighted the operation and maintenance aspect as one of the most important aspects of FM, because it preserves and maintains buildings as valuable assets and functional structures. Moreover, to be par with the rapid development of new management philosophies and technologies, the organisations are geared towards implementing innovative FM strategies (Weerasinghe & Sandanayake, 2013). Maintenance management has recently begun to invest in smart technologies to enhance service supply in a novel way (Talamo, et al., 2019). Further, the authors highlighted that the use of sensor-networked dynamic systems in maintenance can lead to changes in FM decision-making processes and knowledge management. Maintenance has progressed from failure-based maintenance to predictive maintenance (PdM), and it is now realized as the essence of a process-oriented "holistic" approach (Alsyouf, 2007). Over the last few years, there has been a significant shift in the approach to maintenance management, with a strong emphasis on the value of innovation (Goyal & Pitt, 2007). The maintenance management field can achieve greater added value by switching toward novel maintenance strategies (Hemmati et al., 2018). Modern organizations are now attempting to maintain high asset reliability and availability while keeping maintenance costs to a minimum (Neelamkavil, 2011). Further, the author highlighted that developing a maintenance strategy for individual assets that meet corporate goals while requiring minimal investment remains a challenge. Obviously, the application of the Industry 4.0 concept for effective PdM under FM has numerous implementation challenges, which require appropriate strategies to overcome them. Sivanuja and Sandanayake (2022) highlighted the importance of identifying strategies to overcome technology, investment, data, employees, integration, standardization, communication and security-related challenges faced by facilities managers in applying the Industry 4.0 concept for effective PdM. Thus, the study aimed to identify strategies to overcome the challenges in applying Industry 4.0 concept for effective PdM in FM. This paper starts with a

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literature review on Industry 4.0 and challenges in implementing Industry 4.0 for PdM. Section 3 presents the research methodology. The research findings and discussion are presented in Section 4 followed by conclusions and recommendations.

2. APPLICATION OF INDUSTRY 4.0 FOR PdM in FM: A REVIEW

Maintenance is the most expensive aspect of any organization's operational budget (Garg & Deshmukh, 2006). However, with the constant demand to lower costs while adding value to an organization, the position of facilities managers has continued to evolve (Okoro & Musonda, 2019). Garg and Deshmukh (2006) highlighted that present maintenance management is facing difficulties in managing its output effectively and efficiently in terms of people and materials. Moreover, Motawa and Almarshad (2013) highlighted that existing FM systems are unable to record and retrieve detailed information and knowledge generated by building maintenance or operations, such as causes of failure, and reasons for choosing specific maintenance approaches. FM is a highly changing profession and hence, it requires frequent updates (Abeysinghe & Senaratne, 2014). However, large organizations must consolidate an integrated approach that will provide facilities managers with a systematic tool for facilities maintenance throughout the buildings' and infrastructures' entire service life (Shohet & Lavy, 2004). To ensure optimal performance and productivity, it is critical to have an effective approach that efficiently coordinates the failure prediction or detection and maintenance plan (Sang, Xu & De Vrieze, 2021). So, the concept of PdM is built on applying data analytics tools to evaluate operating data received via sensors which have the potential to close the gap in maintenance procedures by assisting FM teams in taking proactive measures to prevent unanticipated failures without the requirement for costly and time-consuming site inspections (Bouabdallaoui et al., 2021). Maintenance 4.0 is a subset of smart manufacturing systems that can detect faults and initiate maintenance actions on their own (Kaur *et al*., 2018). Industry 4.0-enabled implementations are facilitated with the usage of smart technologies such as big data analytics, Cyber-Physical Systems (CPS), autonomous robots, Cloud Computing, Industrial Internet of Things (IIoT), cybersecurity, Machine Learning (ML), Augmented Reality (AR), Data Mining (DM), system integration and simulation (Bousdekis, Apostolou, & Mentzas, 2020; Li, Wang, & He, 2016). The usage of complex machine and equipment in the current industry has dramatically expanded with the introduction of Industry 4.0 concept (Sang et al., 2021).

2.1 CHALLENGES IN USING INDUSTRY 4.0 FOR PDM IN FM

Industry 4.0 is aided significantly by major Industry 4.0 technologies (Sezer et al., 2018). However, in the complex and dynamic Industry 4.0 manufacturing environment, PdM has various challenges in terms of practical implementation (Bousdekis et al., 2020). Sivanuja and Sandanayake (2022) have identified technology, investment, data, employees, integration, standardization, communication and security-related challenges in applying the Industry 4.0 concept for carrying out PdM in FM. Table 1 reviews the challenges of using Industry 4.0 for PdM in FM.

Table 1: Challenges in using Industry 4.0 for PdM in FM

Challenges	References
Technological challenges	
Lack of technological knowledge to handle sophisticated computer solutions	[3], [5], [20]
Ignorance of Industry 4.0 technologies	[14]
Implementation and adoption challenges	[18]
Investment challenges	
Lack of capital for investment	[1], [5], [10], [13], [15]
Uncertain returns from investments	[14]
Data challenges	
Lack of adequate real-time and historical data	[2], [17]
Need to manage, store and process voluminous data	[11], [12], [13], [14]
Unstructured data format	[6]
Insufficient data processing power	[6], [17]
Poor data quality	[8]
Inability to derive information from data	[8], [14], [17]
Challenge in using production data as a catalyst for Industry 4.0 initiatives	[20]
Employees related challenges	
Lack of employees towards knowledge upgrades	[2], [3]
Scarcity of industry 4.0 skilled experts or employees	[4], [10], [15], [22]
Lack of organizational interest in change	[2], [21]
Need to invest in data analytics roles	[2]
Integration Challenges	
Create a synergy between organizational systems and their respective productive teams	[21]
Lack of integration between systems	[5], [8], [10], [22]
Enable internal data sharing in the system	[24], [25]
Standardization Challenges	
Absence of a well-established uniform standard solution	[1], [7], [12], [14]
Communication Challenges	
A lack of internet access	[14]

Challenges	References
Security Challenges	
Insecure connectivity protocols	[9], [10]
Lack of investment to invest in huge security and protection for databases	[16], [19]
Need for data protection	[5], [9], [10]
References: [1] Agarwal & Brem (2015), [2] Bousdekis et al. (2020), [3] Chien et al. (2017), [4] Fettermann et al. (2018), [5] Ghobakhloo, (2018), [6] Kiangala & Wang (2018), [7] Leitao et al., (2016), [8] Li et al., (2017), [9] Luthra & Mangla, (2018), [10] Moktadir et al., (2018), [11] Nikolic et al., (2017), [12] Rajput & Singh, (2019), [13] Ruiz-Sarmiento et al., (2020), [14] Singh et al., (2019), [15] Tortorella & Fettermann, (2018), [16] Dalenogare et al., (2018), [17] Fernandes et al., (2021), [18] Frank et al., (2019), [19] Lezzi et al., (2018), [20] Moeuf et al., (2018), [21] Muller et al. (2018), [22] Oztemel & Gursev, (2020) [23] Sung, (2018), [24] Xiang et al., (2018), [25] L.D. Xu, Xu, & Li, (2018)	

Various manufacturing sectors and/or industrial areas are increasingly interested in implementing Industry 4.0 technology to generate competitive advantage strategies such as PdM methods (Sezer et al., 2018). The above table summarised various types of challenges in applying Industry 4.0 concept to PdM related to technology, investment, data, employees, standardization, communication and security challenges. Industry 4.0 interactions are supported by data exchange, not only from the collective system operations but also from the connected environment where the processes are implemented. Data collecting, data processing, and process interaction are all significant challenges faced by industrialists when it comes to the design and execution of PdM. There is a lack of a capable and smart approach for the implementation of Industry 4.0 practically and profitably (Elkaseer et al., 2018). Further, the authors stated that industrial capability must expand beyond current levels, to move towards Industry 4.0 implementation. The evolution of Industry 4.0 is a complicated process that necessitates a thorough understanding of various factors, both conceptually and in terms of the features of emerging technologies, to make the best use of them (Jantunen et al., 2018). Further, the authors stated that Industry 4.0 presents new technologies as well as new challenges for the maintenance field. Hence, there is a need to identify strategies to overcome the challenges in applying the Industry 4.0 concept for effective PdM in FM.

2.2 STRATEGIES USED TO IMPLEMENT INDUSTRY 4.0 CONCEPT FOR PDM

The method for assessing an industry's readiness for Industry 4.0 adoption is based on a proposed standard that allows industrial companies to assess how prepared they are to achieve that goal while also identifying areas of opportunity for the development of actions that will position them in a more favorable position (Pacchini, Lucato, Facchini, & Mummolo, 2019). To achieve comprehensive effectiveness, basic maintenance concepts and management must be created, executed, and enhanced in tandem with technological advancement (Bengtsson & Lundstrom, 2018).

3. Methodology

A comprehensive literature review was conducted first to establish theory-based knowledge from the research area. Industry 4.0, PdM and FM concepts are reviewed from a broader perspective to elaborate on the research problem. The literature review assisted in identifying feasible smart technologies to develop an integration between Industry 4.0 and PdM approach. Hence, to achieve the aim, the research necessitates an in-depth expert opinion to be evaluated descriptively. Thus, this research applied semi-structured interviews through a qualitative research approach. Hence, 15 experts who have expertise in the maintenance sector with knowledge of Industry 4.0 from manufacturing facilities were selected through convenient sampling and interviewed. NVivo software was used in this research to carry out the code-based content analysis.

4. Research Findings

The semi-structured interviews were conducted with 15 maintenance field experts from Australia, Qatar, Dubai, Singapore and Sri Lankan manufacturing industries, who have Industry 4.0 awareness and knowledge. The profile of the expert respondents is given in Table 2.

Table 2: Profile of the Respondents

Code	Designation	Nature of the organization	Experience	Country
R1	Facilities Coordinator	Food Manufacturing	10 Years	Australia
R2	Facilities Engineer	Food Manufacturing	10 Years	Qatar
R3	Head Industry 4.0 Initiative	Stationary Manufacturing	11 Years	Sri Lanka
R4	Plant Engineer	Cement Manufacturing	20 Years	Sri Lanka
R5	Facilities Engineer	Food Manufacturing	09 Years	Dubai
R6	FM Estimation Engineer	Food Manufacturing	08 Years	Qatar
R7	Facilities Engineer	Food Manufacturing	09 Years	Dubai
R8	Mill Manager	Food Manufacturing	20 Years	Sri Lanka
R9	Senior Reliability Engineer	Tyre Manufacturing	08 Years	Sri Lanka
R10	Facilities Engineer	Food Manufacturing	09 Years	Dubai

R11	Maintenance Manager	Food Manufacturing	12 Years	Singapore
R12	Maintenance Engineer	Food Manufacturing	10 Years	Sri Lanka
R13	Head of Autonomation	Garment Manufacturing	10 Years	Sri Lanka
R14	Engineering Maintenance Manager	Cement Manufacturing	15 Years	Singapore
R15	Senior Factory Engineer	Cement Manufacturing	16 Years	Sri Lanka

R3 is from a manufacturing firm where Industry 4.0 strategy is developed and their system indicators are clearly defined (Intermediate stage in the Industry 4.0 Ladder). Further to establish strategies for applying Industry 4.0 for PdM in FM, it is essential to consult with experts in the maintenance sector like R1, R2, R4, R5, R6, R7, R8, R9, R10, R11, R12, R13, R14, and R15 who are aware of the technology. The research findings on the strategies to enhance Industry 4.0 application to PdM in FM are discussed below.

4.1 STRATEGIES TO ENHANCE INDUSTRY 4.0 APPLICATION TO PDM IN FM

Strategies to enhance Industry 4.0 application to PdM in FM were gathered through the opinions of the respondents and a coding structure was developed for each type of challenge as discussed below.

4.1.1 Strategies to overcome technological challenges

Industry 4.0 is a digital transformation, which requires the support of smart technologies. Industries must overcome these technological challenges to achieve intended Industry 4.0 benefits. Strategies to overcome technological challenges acquired from the respondents are presented in Figure 1.

Name	Files	References
Strategies to Overcome Technological Challenges	15	45
Lack of technological knowledge to handle sophisticated computer solutions	15	15
Facilitate with technological training	13	13
Outsource and learn it	1	1
Use a Digital Adoption Platform (DAP)	1	1
Ignorance of Industry 4.0 technologies	15	15
Provide awareness on smart technologies	12	12
DEMO programmes to accomodate technologies	3	3
Implementation and adoption challenges	15	15
Facilitate employees with proper knowledge and application	7	7
Support the change management process	6	6
Organize DEMO programmes	2	2

Figure 1: Strategies to overcome technological challenges in implementing Industry 4.0 for PdM

The majority of respondents proposed facilitating technological training to overcome the lack of technological knowledge-related challenges. Respondents were instructed to provide awareness of smart technologies to overcome ignorance of Industry 4.0 technologies. Further, respondents stated that, organizing DEMO sessions and practical sessions related to smart technologies will make employees move forward with technologies. Finally, most of the respondents replied to facilitate employees with proper knowledge and application of the implementation, to overcome implementation and adoption challenges.

4.1.2 Strategies to overcome investment challenges

Investment challenges are very common in industries. Industrial transformation requires a high initial cost. Industries must overcome these investment challenges to implement the Industry 4.0 concept. Strategies to overcome investment challenges are shown in Figure 2.

Name	Files	Reference
Strategies to Overcome Investment Challenges	15	30
Uncertain returns from investments	15	15
Proper application of the implementation	8	8
Market intelligent survey and analysis	5	5
Have a backup investment plan	2	2
Lack of capital to investment	15	15
Reinvest the profit	1	1
Convince the top management to invest	14	14

Figure 2: Strategies to overcome investment challenges in implementing Industry 4.0 for PdM

Most of the respondents suggested proper planning and applying the implementation to avoid uncertain returns from the investment. Further, conducting market intelligence surveys and analyses will aid the industries to avoid

uncertain returns from the investment. Moreover, the majority of the respondents agreed that lack of capital to invest in a generic challenge and they answered similarly as "*convince the top management to invest*".

4.1.3 Strategies to overcome data challenges

Data plays a significant role in the fourth industrial revolution. Initially, it is difficult to collect, manage, process and analyse data. Industries must overcome these data challenges to derive the actual benefits of the implementation. Strategies to overcome these data challenges are presented in Figure 3.

Name	Files	References
Strategies to Overcome Data Challenges	15	111
Lack of adequate real-time and historical data	15	20
Computerize manual database	6	6
Increase the source or sensor	14	14
Need to manage, store and process voluminous data	15	15
Create data warehouses	3	3
Use cloud platform	9	9
Use optimized data	3	3
Unstructured data format	15	15
Use Data Science options	9	9
Use NoSQL database	6	6
Insufficient data processing power	15	15
Use Cloud infrastructure	15	15
Poor data quality	15	15
Clean up the original source of data	3	3
Data cleaning and pre-processing	6	6
Engage in more data collection	5	5
Inability to derive information from data	15	16
Process the data using different methodologies	7	7
Use visulaization tools	3	3
Using Data Science options	6	6
Using production data as a catalyst for Industry 4.0 initiatives	15	15
Use Data Science options	14	14
Use deduplication technology to avoid same repetitive data	1	1

Figure 3: Strategies to overcome data challenges in implementing Industry 4.0 for PdM

Respondents answered to computerizing the manual database to overcome the lack of historical data and advised increasing the number of sensors or sources to overcome the lack of real-time data. A higher number of respondents suggested using cloud technology to overcome the need to manage, store and process voluminous data. Further, the majority of respondents recommended using data science options such as Big Data Analytics and Data Mining. All respondents valued the usage of cloud technology to overcome insufficient data processing power. Moreover, the majority of respondents suggested doing data cleaning and pre-processing to get rid of poor data quality. A high number of respondents answered to process the data using different methodologies to overcome the inability to derive information from data. Further, they suggested using data science options and visualization tools to derive meaningful information from data. A substantial number of respondents asked to use data science options like IIoT to collect data from the source, cloud storage to store voluminous data, process the huge data set through Big Data Analytics and derive information from ML and DM, to overcome the challenges based on utilizing production data as a catalyst for Industry 4.0 initiative. After providing strategies for the data challenges, all respondents commented on the possibility of the data challenges in the Industry 4.0 implementation. They mentioned that smart technologies have solutions for all the above-mentioned data challenges.

4.1.4 Strategies to overcome employees' related challenges

Employees are always resistant to change. Industrial changes are growing concerns for employees. So, industries have to overcome these employees related challenges to facilitate proper implementation. Strategies to overcome these employees' related challenges are shown in Figure 4.

There is a mandatory requirement to invest in data analytics roles. Most of the respondents suggest investing in internal employees whereas comparatively few respondents proposed hiring or recruiting data analysts. Experts highlighted that providing proper knowledge and increasing employee involvement towards Industry 4.0 implementation will aid the management to easily direct the organization towards change management. A high number of respondents mentioned that providing adequate training is an appropriate strategy to overcome the lack of employees' interest in knowledge upgrades.

Name	Files	Reference
Strategies to Overcome Employee related Challenges	15	62
Scarcity of industry 4.0 skilled experts or employees	15	15
Hire or outsource industrial experts.	15	15
Need to invest on data analytics roles	15	15
Invest on internal employees	9	9
Hire or recruit data analyst	6	6
Lack of organizational interest towards change	15	15
Provide proper knowledge towards the implementation	10	10
Increase the involvement of employees.	5	5
Lack of employees towards knowledge upgrades	15	17
Provide adequate training	13	13
Encourage self-learning	4	4

Figure 4: Strategies to overcome employees related challenges in implementing Industry 4.0 for PdM

4.1.5 Strategies to overcome integration challenges

Industries might face integration challenges while transforming the current industry into a digitized industry. Industries cannot fully change the systems from an existing system to smart systems at once. They have to gradually switch towards the new smart systems. Until that, industries have to maintain both old and new systems parallelly. So, integration challenges have to be addressed. Strategies to overcome these integration challenges are presented in Figure 5.

Name	Files	References
Strategies to Overcome Integration Challenges	15	45
Create a synergy between organizational systems and their respective productive teams	15	15
Establish proper communication and collaboration between teams	11	11
Adequate knowledge on implementation	4	4
Lack of integration between systems	15	15
Use integration tools	8	8
Automate the systems	7	7
Enabling data sharing in system	15	15
Design new system by complying the requirements	13	13
Incorporating data management and data governance	2	2

Figure 5: Strategies to overcome integration challenges in implementing Industry 4.0 for PdM

Respondents suggested establishing proper communication and collaboration between productive teams to overcome creating a synergy between organizational systems and their respective productive teams. Moreover, each team must possess adequate knowledge regarding the implementation. Most of the experts recommended automating the system as much as possible and using integration tools to overcome the integration between the systems. Finally, the majority of respondents were asked to design a new system by complying with the requirements to enable data sharing in the systems.

4.1.6 Strategies to overcome standardization challenges

Standardizing the application of smart technologies will ensure their interoperability, compatibility and security along with the industrial processes. So, standardization requires immediate consideration in the industry while implementing Industry 4.0. Strategies to overcome these standardization challenges are presented in Figure 6.

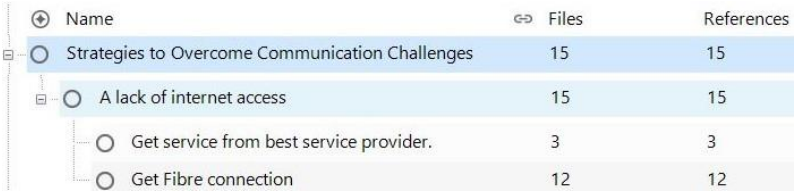
Name	Files	References
Strategies to Overcome Standardization Challeges	15	15
Absence of a well-established uniform standard	15	15
Establish internal standard solutions	7	7
Follow available standard policies	8	8

Figure 6: Strategies to overcome standardization challenges in implementing Industry 4.0 for PdM

Respondents proposed two strategies to overcome these standardization challenges such as, (1) following already available standard policies and (2) establishing internal standard solutions in alignment with the implementation.

4.1.7 Strategies to overcome communication challenges

Industry 4.0 concept relies on data communication by which all real-time decisions are taken. Communication challenges affect the Industry 4.0 implementation. Strategies to overcome communication challenges are presented in Figure 7.



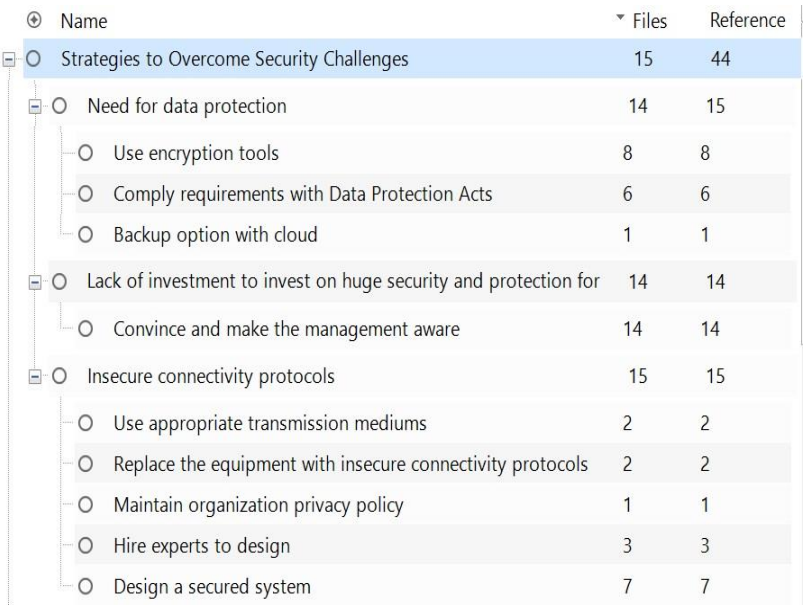
Name	Files	References
Strategies to Overcome Communication Challenges	15	15
A lack of internet access	15	15
Get service from best service provider.	3	3
Get Fibre connection	12	12

Figure 7: Strategies to overcome communication challenges in implementing Industry 4.0 for PdM

The majority of the respondents suggested getting a Fibre internet connection for the industries to get uninterrupted service from Industry 4.0 implementation. Some respondents recommended getting internet service from the best service providers.

4.1.8 Strategies to overcome security challenges

The importance of cyber security is growing. Currently, industries are relying on computerized systems to carry out their business processes. Industries must mandatorily ensure the security of industrial data, before entering into smart technology-based industrial platforms. Strategies to overcome these security-related challenges are presented in Figure 8.

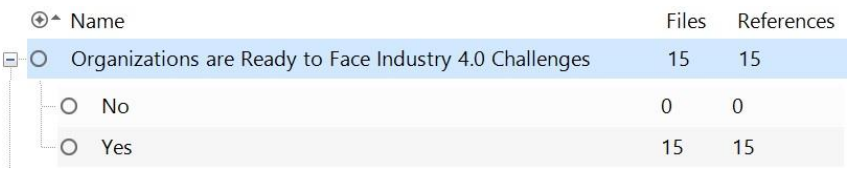


Name	Files	Reference
Strategies to Overcome Security Challenges	15	44
Need for data protection	14	15
Use encryption tools	8	8
Comply requirements with Data Protection Acts	6	6
Backup option with cloud	1	1
Lack of investment to invest on huge security and protection for	14	14
Convince and make the management aware	14	14
Insecure connectivity protocols	15	15
Use appropriate transmission mediums	2	2
Replace the equipment with insecure connectivity protocols	2	2
Maintain organization privacy policy	1	1
Hire experts to design	3	3
Design a secured system	7	7

Figure 8: Strategies to overcome security challenges in implementing Industry 4.0 for PdM

The majority of the respondents recommended using encryption for industrial data during data transmission. Further, some respondents said industries must design the data protection framework by complying with the requirements of data protection acts. All respondents suggested convincing and making the top management aware of the need for cyber security to overcome investment issues. Moreover, to overcome insecure connectivity protocols, respondents suggested designing a secured system. A higher number of respondents recommended hiring experts to design the system, replacing the equipment with insecure connectivity protocols with new equipment with secured connectivity protocols, using appropriate transmission mediums and maintaining organizational privacy policy.

4.2 INDUSTRIES' READINESS TO FACE THESE INDUSTRY 4.0 IMPLEMENTATION CHALLENGES



Name	Files	References
Organizations are Ready to Face Industry 4.0 Challenges	15	15
No	0	0
Yes	15	15

Figure 9: Readiness of industries

Further, respondents were questioned about the readiness of industries to implement the Industry 4.0 concept in their operations. All respondents said that industries are ready to face these Industry 4.0 implementation challenges and findings are presented in Figure 9.

R11 emphasized industries' readiness by citing previous industrial paradigms as "*Industries which practice Industry 3.0 are more curious about Industry 4.0 implementation whereas industries which practice Industry 2.0 are trying to shift towards Industry 3.0*". Moreover, R1 mentioned his opinion by citing maintenance generation as, "*Most of the organization have not even moved into the second generation of maintenance*". R3 supported his view on the readiness of the industry by citing his organization's progress on Industry 4.0 implementation. "*We are in the intermediate level (2-3) in Industry 4.0 ladder (Industry 4.0 strategy developed and system of indicators defined – Industry 4.0 investments at a low level)*". R7 stated the need for smart technologies in the industry and expectations of industries through her work experience, "*With the recent experiences in COVID-19, we have seen clients asking for smart solutions or IoT solutions with very low human interventions*". Some respondents explained the real challenges, which restrict Industry 4.0 implementation as below.

R4, R6 and R8 described the situation of the industry by pointing out investment, payback and implementation period-related challenges. Additionally, R4 and R6 highlighted the challenge of educating the employees and adapting themselves to Industry 4.0 implementation. R8 mentioned that "*Industries are focusing on virtual collaboration, computational and adaptive thinking to overcome these Industry 4.0 related implementation challenges*". R10, R13 and R14 said that industries are always seeking change. R2 and R10 mentioned that the above-identified challenges are initial implementation challenges that can be solved after the proper implementation of Industry 4.0. Moreover, R10 emphasized that "*Once the machines are connected to the system under Industry 4.0 norm, then intended benefits can be derived from the implementation*". R13 further mentioned that "*Industries will move to Industry 4.0 to attract the younger workforce*". R15 stated that "*Industries are now checking the feasibility of applying Industry 4.0 to their manufacturing activities and practices*". R5 and R12 mentioned industries are getting ready to derive the intended benefits to the organizations. Further R12, specifically mentioned achieving a flexible smart system for manufacturing purposes.

5. Conclusions and Recommendations

FM input appears to be essential in the forthcoming industry. Maintenance management approaches evolve from time to time in a way to fulfill arising maintenance requirements. However, many challenges are existing in executing the current maintenance approaches. Due to the fourth industrial revolution, predictive maintenance is expected to rise significantly in the upcoming decades. Industries are trying to implement novel proposals to increase their business efficiency. Novel implementations can be either an upgrade to the existing system or a complete change to a new system. So, implementation challenges are very common in the industry. The literature review identified technological, investment, data, employee, integration, standardization, communication and security-related challenges that affect the implementation of the Industry 4.0 concept to enable smart PdM for FM. Shifting from current industrial practice to Industry 4.0 practice is a challenge. Embracing the change is still challenging in the 21st century. However, experts proposed strategies such as technological training, hiring experts, team communication and collaboration, using data science, integration and encryption tools, following standard policies and getting fiber connection to overcome the challenges in implementing Industry 4.0 for PdM in FM. Initial implementation challenges can be resolved after Industry 4.0 has been properly implemented. Even with contemporary technological advancements, technological adaptations are very minimal. To survive in the era of industrial transformation, organizations need to assess their readiness for Industry 4.0. Organizations' readiness toward Industry 4.0 has been studied from the perspectives of technology, investment, data, employee, integration, standardization, communication and security. Maintenance practitioners involved in FM can apply the findings of this study on Industry 4.0 challenges and their overcoming strategies for applying PdM to enhance the overall effectiveness of the maintenance process.

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