Industry 4.0 and Society 5.0 through Lens of Condition Based Maintenance (CBM) and Machine Learning of Artificial Intelligence (MLAI)

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Abstract. This paper provides preliminary discourse on buzz words about Industry 4.0 and Society 5.0. This discourse focuses on the lens of Condition Based Maintenance (CBM) and Machine Learning of Artificial Intelligence (MLAI). To some extent several companies have embarked Industry 4.0 and Society 5.0 within Internet of Things (IoT) technology. Through the wave of IoT Technology, Industries are adopting automated machinery. Predictive maintenance (PM) is indispensable not only toward the machines‟ vitality and longevity purpose, but also toward the human error reduction. This paper elaborates its discourse of Industry 4.0 and Society through the lens of CBM and MLAI. The mentioned Machine Learning, in this paper, refers to research methodology, as methodological frameworks. Those frameworks comprise several phases, which are: 1. Equipment Analysis; 2. Data Evaluation; 3. Data Selection and Process; 4. Modeling; 5. Decision Support Model Evaluation. The MLAI techniques are based upon the identification of behaviour patterns. This identification comprises datasets that exclude mathematical models or prior historical knowledge. The discourse in this paper intertwines CBM process and MLAI through data cleaning and processing, features stratification and extraction, model stratification and validation. This paper elaborates two renowned maintenance approaches which are preventive and corrective maintenance. Discourse in this paper focuses on corrective action, known as predictive maintenance (PM), or condition based maintenance (CBM) within Reliability Centered Maintenance (RCM). CBM is chosen as the most desirable strategy, as it involves the intervention as the consequence of the machine breakdown. It also provides cost savings toward spare parts consumption, and optimizes production.

Keywords: Industry 4.0, Society 5.0, Condition Based Maintenance, Machine Learning, Artificial Intelligence.

1. Introduction

Condition Based Maintenance (CBM)

The mentioned Machine Learning, in this paper in Figure 1, refers to research methodology, as CBM methodological frameworks Those frameworks comprise several phases, which are: 1. Equipment Analysis; 2. Data Evaluation; 3. Data Selection and Process; 4. Modeling; 5. Decision Support Model Evaluation [1].

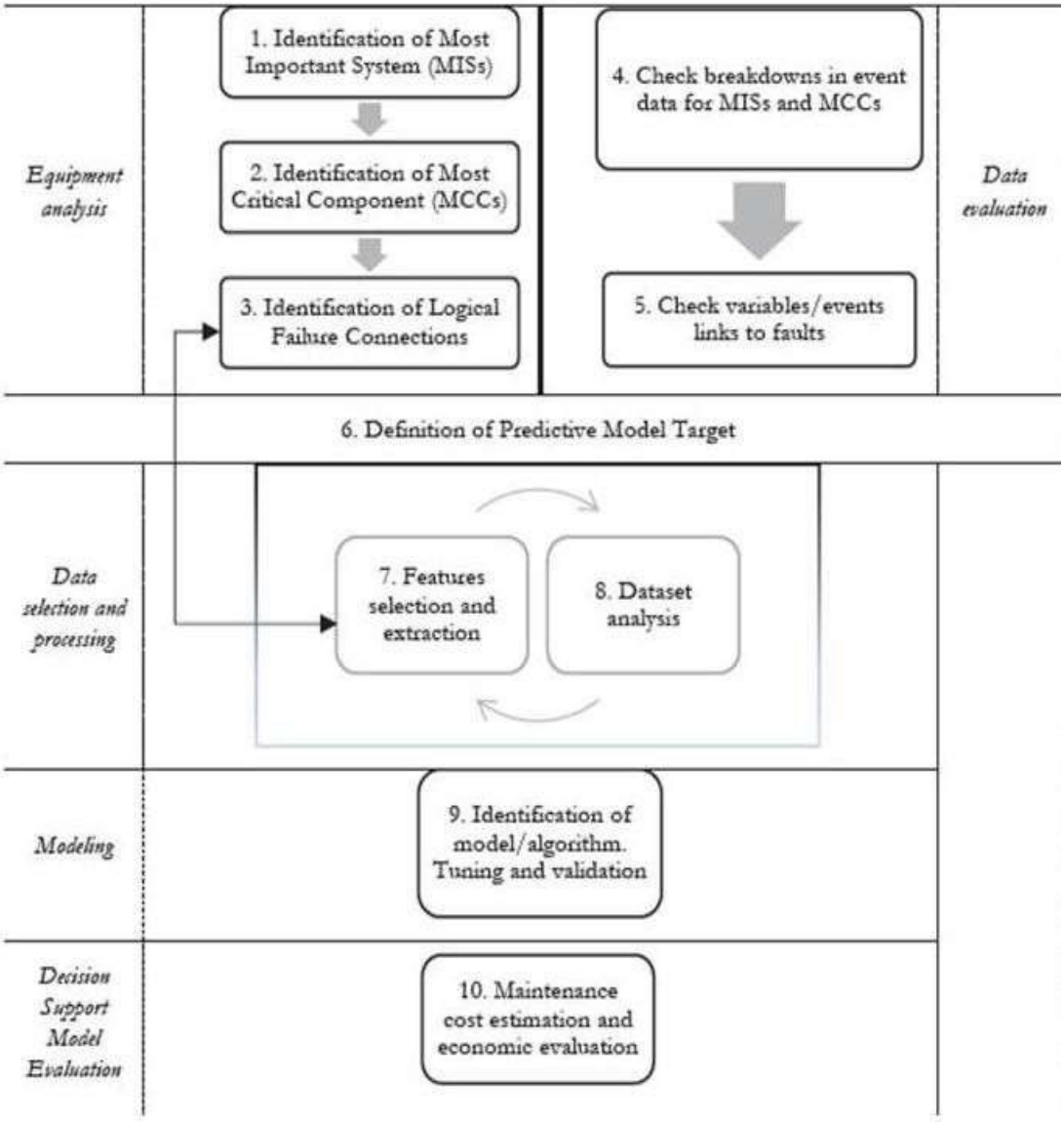

Figure 1 Condition Based Maintenance (CBM) Methodological Framework

It is indispensable to choose the appropriate maintenance policy due to its difficulty to quantify. This paper elaborates two renowned maintenance approaches which are preventive and corrective maintenance. Discourse in this paper focuses on corrective action, known as predictive maintenance (PM), or condition based maintenance (CBM) within Reliability Centered Maintenance (RCM). CBM is chosen as the most desirable strategy, as it involves the intervention as the consequence of the machine breakdown [1].

As CBM is chosen as the most desirable strategy, there is the need to implement it through assorted techniques. Those techniques are implemented in data processing, diagnostics, and prognostics for implementing CBM as illustrated in Table 1.

Table 1 Survey of Condition Based Maintenance Techniques

Phase	Techniques
Data processing	– Kalman filtering – Time–frequency/time–frequency moments – Wavelet analysis – Autoregressive (AR) model – Fourier analysis – Wigner–Ville analysis – Fuzzy logic – Artificial Neural network – Genetic algorithms – Statistical pattern recognition – Hidden Markov model – Support Vector Machine – Decision tree induction
Diagnostics	– Logistic regression – Artificial Neural network – Reliability theory – Statistical analysis (e.g. Regression) – Time series data analysis
Prognostics	– Case Based Reasoning (CBR) – Renewal theory – Math programming – Simulation
Maintenance operation	– Multi-Criteria Decision Making (MCDM)

By interpretation and definition, preventive maintenance schedule is arranged based upon manual or the estimation of average time between failures.Meanwhile, corrective maintenance schedule is arranged based upon intervention as the consequence of the breakdown. Both strategies necessitate company ability to tackle resources inefficiencies and productive capacity inadequacy [2, 3].

Both strategies entail CBM that include: 1. the maintenance problem formulation and segregation of machine or facility; 2. the operational model interpretation and the insight of the failure mode for ascertaining predictive model objectives [4, 5].

The mentioned inclusion necessitates data manipulation phases, which are: selection, analysis, processing, modelling and evaluation. Those phases are intended for testing model feasibility. Ultimately, the phase continues with decision-support maintenance system implementation . As first thing first, the rudimentary phase consists of imperative phase for ultimate model that address root causes of maintenance issues toward analysis and indispensable decision support [6, 7].

Machine Learning of Artificial Intelligence (MLAI)

The MLAI techniques are based upon the identification of behaviour patterns. This identification comprises datasets that exclude mathematical models or prior historical knowledge. The discourse in this paper intertwines CBM process and MLAI through data cleaning and processing, features stratification and extraction, model stratification and validation.

The objective of this research refers to probe a methodological framework development. This development triggers guidance for maintenance engineers to create MLAI-based CBM, with maturity and quality indicators. Furthermore, the objective is to identify the most influential keywords toward CBM research among 50 most cited papers [8, 10].

R	Word	Frequency Word
1	Condition-based maintenance	12
2	Maintenance	10
3	Prognostics	9
4	Predictive maintenance	6
5	Diagnostics	4
6	Reliability	4
7	Remaining Useful Life (RUL)	4
8	Replacement	4
9	Identification	3
10	Markov process	3
11	Optimisation	3
12	Inspection	2
13	Aging	2

Figure 2 Most popular keywords in 50 most cited papers in CBM.

Industry 4.0 and Society 5.0

Briefly, Industry 4.0 appeared from innovative digital technology, aiming for value creation. Meanwhile, Society 5.0 is deemed as society that focuses on human interaction society, in order to create economic encroachment to intertwine Industry 4.0.

As the constraint, the environment has stipulated natural resources that lead to accelerated augmentation of sustainable‟s industries and economies [9].

2. Research Methodology and Methods

2.1. Research Methodology

In this paper, research methodology is known as CBM methodological frameworks Those frameworks is previously listed in Figure 1, and comprise several phases, which are: 1. Equipment Analysis; 2. Data Evaluation; 3. Data Selection and Process; 4. Modeling; 5. Decision Support Model Evaluation.

2.2. Methods as Appproaches to CBM as chosen strategy

This paper, as the extended approaches, capitalizes several approaches such as Pareto Chart, Fishbone Diagram, Risk Matrix, Condition-based Maintenance (CBM) and Productivity.

Pareto Chart focuses on savings the most influential great cost. Furthermore, Fishbone Diagram is beneficial to identify problem‟s root cause. Subsequently, the Risk Matrix is considered as methods to segregate the compilation of work priority.

Above all, as the arching consideration, the capitalization of CM is indispensable to calculate Key Performance Indicator (KPI) toward implementation of Preventive Maintenance and Productivity. Ultimately, as the ultimate consideration, CBM is beneficial to tackle resources inefficiencies and productive capacity inadequacy.

3. Results and discussion

This paper combined both theoretical perspective and its managerial implementation within a company in Qatar. The mentioned company experienced a minus profit in 2016, as illustrated in Figure 3. This profit is originated from the reduced and plunged Amonia and Urea price that trigger 20% employee reduction and eventually number of work order backlogs. These backlogs have to be solved through Condition Based Maintenance through work planning, the amount of Periodical maintenance (PM) assignment.

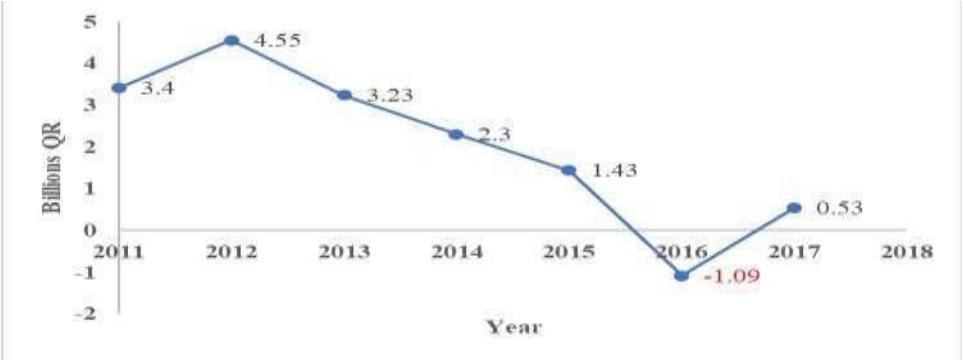

Figure 3 Profits in Billions Qatari Rial (QAR)

Several continuous improvement and breakthrough are intended to bounce the financial and non financial performance of this minus profit that converge into the one of the root causes toward Preventive Maintenance (PM). This PM refers to the CBM as the central discourse of this paper and in particular as the chosen strategy.

4. Conclusion

This paper provides preliminary discourse on buzz words about Industry 4.0 and Society 5.0. This discourse focuses on the lens of Condition Based Maintenance (CBM) and Machine Learning of Artificial Intelligence (MLAI).

To some extent several companies have embarked Industry 4.0 and Society 5.0 within Internet of Things (IoT) technology. Briefly, Industry 4.0 appeared from innovative digital technology, aiming for value creation.

Meanwhile, Society 5.0 is deemed as society that focuses on human interaction society, in order to create economic encroachment to intertwine Industry 4.0. As the constraint, the environment has stipulated natural resources that lead to accelerated augmentation of sustainable‟s industries and economies.

Through the wave of IoT Technology, Industries are adopting automated machinery. Predictive maintenance (PM) is indispensable not only toward the machines‟ vitality and longevity purpose, but also toward the human error reduction.

This paper elaborates its discourse of Industry 4.0 and Society through the lens of CBM and MLAI. The mentioned Machine Learning, in this paper, refers to research methodology, as methodological frameworks.

Ultimately, it is intertwining discourse in this paper on the theoretical and managerial implication, especially for the company in Qatar as the unit of analysis.

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