Conceptual Analysis and Survey of Total Productive Maintenance (TPM) and Reliability Centered Maintenance (RCM) Relationship

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Abstract. Maintenance is an important issue that needs to be addressed during the design and manufacturing or building of a system. Both Total Productive Maintenance (TPM) and Reliability Centered Maintenance (RCM) have its own concepts and principles as a maintenance strategy to give impact to the performance and reliability of the system. Therefore, in this research, the TPM will be studied with RCM to show their relationship. Based on the conceptual analysis, the author will analyze publications from journals, books, and articles to find all related information, such as genealogy, definition, concepts, and principle, and implementation of both strategy. The conceptual method used is Näsi's four elements of conceptual analysis and a questionnaire survey method which has been answered electronically to study the current maintenance strategies in the real industries and to relate it to TPM and RCM. The result of the study shows that TPM had started in 1970 while RCM started in the 1960s, but the foundation of TPM and RCM was started in 1950s with Breakdown Maintenance (BM). TPM is basically about elimination of faults through day-to-day activities involving the entire force work while the concept of RCM is to improve equipment reliability. The objective of TPM is to achieve zero breakdowns, zero defects, and zero accidents while TPM is to preserve the functions. Although both are using different tools but both are linked together through the Lean Tool and can increase product quality, equipment reliability, increase safety, and increase profit. From the survey result, most of the respondent comes from the companies that implementing traditional maintenance (PM and CM) rather than TPM and RCM. TPM mostly can be implemented in big plant industries while RCM can be applied in small or medium size plant.

1. Introduction
Along with rapid changes of technology and competition among industries, organizations employ different strategies and policies to increase productivity and decrease costs. Nowadays, companies have to meet competition from all over the world. Maintenance is one of a policy which is used to cut costs, increase productivity and to continue with the global competition. A lot of maintenance strategies have been developed over the years. Maintenance plays an important role in the production system because it is a largest controllable cost and status quo represents a challenge for leading managements to re-evaluate their maintenance strategies and decision making work attempts to
understand different maintenance policies making for better maintenance of assets. So, the efficiency of maintenance systems can affect the profit of a plant. Therefore, selecting appropriate maintenance policies are vital for each manufacturing company. An organization can save huge amount of time, money, and the useful resources in dealing with reliability, maintainability, and performances.

A company can use an innovative approach which is a Total Productive Maintenance (TPM) to maintenance and optimizes equipment efficiency, eliminates faults and promotes autonomous maintenance between operators, through day-to-day activities involving the entire force work [1]. According to Nakajima (1988), as cited by Lycke [2], TPM is an approach that involves employees from the maintenance department and the production department to equipment management. An autonomous maintenance by operators and small group activities in every department and at every level. All improvements should be standardized and maintained because TPM is continuous improvements focusing on the equipment and the production.

Maintenance concepts such as Reliability Centered Maintenance (RCM) have been successfully applied in the process industry to reduce unnecessary preventive maintenance actions and come up with a systematic and efficient maintenance plan. RCM is a most systematic and efficient process to address an overall programmatic approach to the optimization of plant and equipment maintenance. Maintenance needs of the process plants equipment can be better addressed with RCM approach. Failure Mode and Effect Analysis (FMEA) help in identifying all possible causes of failure with a specific reference to the component of systems and sub-systems [3-4]. RCM is a technique for prioritizing the maintenance strategy in a systematic and logical manner. The primary objective of RCM is to preserve functions [5].

Worldwide competition is dependent, among other things, on deregulation, technical development, increased global trading, internationalization, and new principles for organization and management. This paper focus on a conceptual analysis of TPM and RCM, the similarities and differences between both strategies. The relationship between TPM and RCM will help organizations to simplify the process of implementing TPM and RCM. The analysis of these findings will form the basis for recommendations and guidance for organizations, which intend to implement both TPM and RCM. So, the success implementation of both maintenance can be achieved.

Näsi's four elements of concept analysis were employed to investigate the relationship between TPM and RCM. A questionnaire survey technique has been developed in the present study to gather informations and establish the relationship of TPM and RCM. The structured questionnaire was sent to manufacturing companies around Pulau Pinang to find the correlation and level of implementation of TPM and RCM.

2. Methodology
This research uses conceptual analysis method of Näsi’s four elements of concept analysis published by Anita Nuopponen [6] to study the conceptual analysis of TPM and RCM and to investigate the relationships of TPM and RCM. The published journals from several of authors that is related to this topic was studied from different publication years. Subsequent, survey method has been studied to choose the right survey technique to study the relationship of TPM and RCM with respect to the real application in industry. A structural questionnaire was sent to manufacturing companies around Pulau Pinang to gather information on the topic. Then, all the data will be analysed before come out with a conclusion.

2.1. Conceptual analysis method
In Näsi's four elements of concept analysis, there are four elements in the model as depict in Figure 1. The first element is creating a knowledge foundation, the second one is external analysis, followed by internal analysis and the last element is forming conclusions.
2.1.1. **Element 1: Creating a knowledge foundation.** Firstly, all the information on relevant research and its results about TPM and RCM is gathered. The common information about genealogy, definition, objective and purpose of implementation of TPM and RCM in the literature were gathered. The literature had been limited to only from journals, books, and articles from the different author. In this methodology, it is divided into two parts which is TPM and RCM. Figure 2 shows the element 1 in Näsi's four elements of concept analysis.

![Figure 1. Näsi's four elements of concept analysis](image)

**Figure 2.** Element 1 (creating a knowledge foundation)

2.1.2. **Element 2: External analysis.** Element 2 involves distinguishing and delimiting the concepts to be studied from their superordinate concepts and other related concepts, mean all the concept about TPM and RCM from the literature has been distinguished. In this element, it is focused on separating and understands the concept of TPM and RCM. The authors conducted reviews on previous research about TPM and RCM. All the information from Element 1 such as definition, history, objective, implementation and all principle that already mentioned in the paper is distinguished and the characteristic reviewed. Then the data was analysed from each perspective. This element also applied for both of TPM and RCM.

2.1.3. **Element 3: Internal analysis.** In Näsi's internal analysis Element 3, the concepts between both TPM and RCM are analysed in different views and the concepts are broken down into their parts. This element reanalysing and combining all research that discussed both TPM and RCM to differentiate between the terms discussed. The author discussed the link between TPM and RCM. Element 2 focussed only on the view of TPM and the view of RCM individually from different kinds of literature but in element 3, the focused is more on the relationship between TPM and RCM as visualised in Figure 3, the input from Element 2 will helps in reanalysing steps in Element 3 to give an input of Element 4.

![Figure 3.](image)
2.1.4. Element 4: Forming conclusions. Finally, forming conclusions about the conceptual analysis of TPM and RCM. In this step, the solutions to concept problems are offered. Solutions could be either modifying or accepting the old concepts, or even forming new concepts. Then, the similarity and the differentiation between TPM and RCM are documented. As shown in Figure 4 an input from Element 3 further clarified before proceed with the documentation.

2.2. Survey method
Survey method had been employed to collect information in an organised and methodical manner about the implementation of TPM and RCM in industry located in Pulau Pinang. This survey had been broken down into several phases. The first is the planning phase, which is followed by the second phase of the design and development, followed by implementation phase. Finally, the entire survey process is reviewed and evaluated. The phases of the survey are as depicted in Figure 5 [7].

2.2.1. Steps of survey method. A survey is a much more complex procedure than simply asking questions and compiling answers to produce statistics. To yield accurate information, numerous steps must be carried out following precise procedures and method. These steps include formulating the survey objectives, determining the survey frame, determining the sample design, designing the questionnaire, performing data collection, data analysis, and documentation. The steps are as follows.

(i) Formulation of the Statement of Objectives
Statement of Objectives is one of the most important tasks during conducting a survey. This establishes not only the survey’s broad information needs, but the specific topics to be addressed, the
operational definitions to be used, and the analysis plan. In this paper, the main objective for this survey is to study the current maintenance strategies in the real industries and to relate it with the TPM and RCM.

(ii) Selection of a Survey Frame

The survey frame provides the means of contacting and identifying the units of the survey population. It is important to decide who will be included in the survey population. The survey frame should include some or all of the following items such as identification data, contact data and classification data. Identification data are the items on the frame that uniquely identify each sampling unit, such as name, exact address, and a unique identification number. Contact data are the items required to locate the sampling units during collection, for such as mailing address or telephone number. Classification data are useful for selection of sample and possibly for estimation.

(iii) Determination of the Sample Design

This survey can be split into two type which is census surveys and sample surveys. In census survey, data are collected for all units in the population while, in a sample survey, data are collected for only a fraction (typically a very small fraction) of units of the population. Two types of sampling exist which is probability sampling and non-probability sampling. Non-probability sampling provides an easy, inexpensive and fast way of selecting units from the population but uses a subjective method of selection. The data analyst must assume that the sample is representative of the population in order to make inferences about the population from a non-probability sample. This is often a risky assumption given the subjective method of selection. Probability sampling is more costly, more complex, and takes longer time than nonprobability sampling.

(iv) Questionnaire Design

A questionnaire or form can be defined as a group or sequence of questions designed to obtain information on a subject from a targeted respondent. Questionnaires can either be in computerised or paper format. The goal is to obtain information in such a way that survey respondents understand the questions and can provide the correct answers easily in a form that is suitable for subsequent processing and analysis of the data. The questionnaire design process starts with the formulation of survey objectives and information requirements and continues with consult with data users and respondents. Next, review previous questionnaires followed draft the questionnaire before review and revise the questionnaire. Then the questionnaire must be tested and revised and lastly, the questionnaire must be finalized.

(v) Data Collection Methods

Data collection is the process of gathering the required information for each selected unit in the survey. The method of data collection should be chosen in order to achieve a high participation rate and to collect data as complete and accurate as possible while minimising the burden to the respondent and operational constraints. The basic methods of data collection can be divided into two which is Self-Enumeration and Interviewer-assisted (Personal Interviews or Telephone Interviews).

With self-enumeration, the respondent completes the questionnaire without the assistance of an interviewer. There are a variety of ways that the questionnaire can be delivered to and returned by the respondent: by post or facsimile, electronically (including the Internet) or by an enumerator. Self-enumeration methods require a very well-structured questionnaire, simple and easy to follow questionnaire with clear instructions for the respondent. A telephone number detail of respondent must be included to obtain help completing the questionnaire. There is two type of self- Enumeration which is when computer-based it is called Computer-Assisted Self Interviewing (CASI) and when paper-based, this method is called Paper and Pencil Interviewing (PAPI).

The interviewer-assisted consist of two ways. The first one is personal Interviews. These personal interviews involve interviewer and respondent. The interview is conducted in person, usually at the respondent’s residence or work place, although it can be conducted in a public place. The interviewer will assist the respondent to complete the questionnaire. Secondly, an interviewer assists the respondent to complete the questionnaire over the telephone and this is called as Telephone Interviews.
This paper focused on selfEnumeration which required the respondent completes the questionnaire via form created and distributed in internet. This is why simple and easy to understand questionnaire with clear instructions is important to ensure respondents did not experience any confusions and difficulty in understanding the survey questions regarding to the RCM and TPM implementation level in their company.

(vi) Data Analysis

Data analysis must relate the survey results to the questions and issues stated by the statement of objectives. This is one of the most crucial steps in a survey since the quality of the analysis can substantially affect the usefulness of the whole survey. In this step, the data collection will be summarized and interpreted their meaning in a way that provides clear answers to questions that initiated the survey related to TPM and RCM view. This data analysis may be restricted to the survey data alone or it may compare the survey’s estimates with results obtained from other data or survey sources.

(vii) Documentation

Documentation is a final step in survey method. This step provides a record of the survey of TPM and RCM and should encompass every survey step and every survey phase. It may record different aspects of the survey and be aimed at different groups, such as management, engineer, technical staff, and operator. For example, a report on data quality provides users a context for the informed use of the data. A survey report that includes not only what decisions were made, but also why they were made provides management and technical staff with useful information for future development and implementation of similar surveys. During implementation, documentation of procedures for staff helps to ensure effective implementation of TPM and RCM in the real industry.

3. Results

3.1. Conceptual analysis result

In conceptual analysis method, all related information from the selected journals, articles and book were reviewed for both TPM and RCM with respect to the Näsi's four elements of concept analysis. Table 1 shows the concept and the relationship of TPM and RCM.

| Characteristics  | Total Productive Maintenance (TPM)                                                                 | Reliability Centered Maintenance (RCM)                                                                 |
|------------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| History          | i. TPM concept was first introduced in the year of 1970                                          | i. Founded in the 1960s                                                                             |
|                  | ii. Developed based on the concepts and methodologies of Productive Maintenance.                  | ii. Initially oriented towards maintaining airplanes and used by aircraft manufacturers, the government and airlines |
|                  | iii. The concept first introduced by M/s Nippon Denso Co. Ltd, a supplier of M/s Toyota Motor Company, Japan. |                                                                                                        |
| Theory           | i. Promotes autonomous maintenance                                                               | i. Identifying effective and efficient preventive maintenance                                          |
|                  | ii. Eliminates faults through day-to-day activities involving the entire force work               | ii. Improving equipment reliability                                                                  |
|                  | iii. Optimizes equipment efficiency                                                              |                                                                                                        |
| Objective        | i. Zero defects                                                                                   | i. Preserve the functions                                                                            |
|                  | ii. Zero breakdowns                                                                              |                                                                                                        |
|                  | iii. Zero accidents                                                                              |                                                                                                        |
| Process View     | i. Decrease process delay                                                                         | i. The system reliability linked with maintenance process of system                                    |
|                  | ii. Improve process flow                                                                         |                                                                                                        |
From all the definitions, to make it simple to understand, TPM best described as an innovative approach to company maintenance that promotes autonomous maintenance between operators, eliminates faults through day-to-day activities involving the entire force work and optimizes equipment efficiency in order to maximize overall equipment effectiveness, OEE. Autonomous Maintenance (AM) is a program to reduce technicians’ workload through operators’ involvement. Thus, the involvement of operators in maintenance tasks can reduce the workload of technicians [8].

Lean manufacturing is a system that is focused on the processes which minimizing variations and facilitate waste reduction thereby facilitating cost reduction in plants. There are various tools and techniques to implement lean principles to an industry which is 5S, Value Stream Mapping (VSM), Total Productive Maintenance (TPM), Failure Mode and Effect Analysis (FMEA), Total Quality Management (TQM), Quality Function Deployment (QFD), Kaizen and Kanban [9]. TPM is one of the tools used in Lean manufacturing.

The principle of RCM can be described from the definition of RCM. The theory of RCM described by Gajanand Gupta and Rajesh P. Mishra in the year of 2016 [3]. They defined RCM as the function of the operating system to recognize the consequences of the failure by the system function and failure analysis. Various tools used in RCM include Physical Hazard Analysis (PHA), Failure mode and effect analysis (FMEA), Failure mode effect and criticality analysis (FMECA), Optimizing Maintenance Function (OMF), Fault Tree Analysis (FTA), and Hazard and Operability (HAZOP) Analysis [10].

3.2. Survey results
The authors conducted a questionnaire survey with the title “Conceptual Analysis of Total Productive Maintenance (TPM) And Reliability Centered Maintenance (RCM)”. The main objective of this survey is to study the current maintenance strategies in the real industry mainly focussed in Pulau Pinang. This survey involved all people from the top managements to the operator by using self-enumeration data collection method. The survey has been answered through electronically (including the Internet) using the application of Google Forms. The target of respondent for this survey is 21 respondents. All the result of the survey shown in Figure 6 and Figure 7:
The survey is not biased to one gender only but included both male and female. The percentage of male respondents is 66.7% and is higher than the female that just only 33.3% shown in Figure 6. An organization consists of several functional departments works in a team to sustain and develop a successful plant. Figure 7 shows four main type of department that most contribute to the company. The highest respondent percentage which is 42.9% is from production department and the lowest one is 9.5% from quality department.

This survey focused on two level of the business type which is Multi – National Corporation (MNC) and Small and Medium size Enterprises (SME). MNC is corporate giants, typically houses of multiple departments and consist a large pool of staff who generally keeps to their own departments, while an SME is relatively small in size and has employees frequently working across divisions to make end goals meet. From result in Figure 8, most of the respondents come from MNC with percentage of 57.1%.

Maintenance strategies one of the important factors that contribute to increase the production and decrease the production cost. Based on the Figure 9, most of the respondent comes from the companies that implementing Preventive Maintenance and Corrective Maintenance rather than RCM.
Figure 9. Type of maintenance strategies used in an organization.

In overall employee involvement plays important role in developing a strong maintenance system. Figure 10 shows most of the industries involved all the employees in their maintenance activity with resulted in 71.4%. Safety is the first factor need to be considered in choosing a job place. Based on Figure 11, most of the respondent comes from the organization with safe in work environment.

Figure 10. Employees involvement

Figure 11. Safety of work environment

Management commitment to education and training of employees is a key factor in developing an excellent organization system. Based on the Figure 12, 95.2% of the respondent get education and training in their organization.

Figure 12. Management commitment to education and training of employees.
The tool that commonly used in TPM is 5S, OEE, SMED, JIT, and LMC While for RCM is FMEA, PHA, FTA, and HAZOP. All of this tool contribute to the excellent implementation of TPM and RCM. Based on the Figure 13, the highest tool usage in the most respondent organization is 5S with the percentage of 85.7%.

Determination of the effectiveness of maintenance strategies in a certain place can be divided into three stages which are good, fair and bad. Figure 14 shows the percentage of all the stages from all of 21 respondent. The result showed the effectiveness maintenance strategies most of the respondents in a fair stage. This mean, the organization still working towards the good stages.

4. CONCLUSIONS
Näsi’s four elements of concept analysis had been chosen because it is a step by step procedure and very simple to understand compare than other conceptual analysis methods. It has four elements in the model which are Element One: Creating a knowledge foundation, Element Two: External analysis, Element Three: Internal analysis and Element Four: Forming conclusions. For this paper, in element one, found several kinds of literature that related to TPM and RCM. In Element 2, authors breakdown the information in the literature into several parts which is genealogy, definition, principles, and concepts, and implementation of TPM and RCM. Element 3 linked the formation of the Element 2, while Element 4 described and concluded the relation of the information into more simple to understand. Genealogy of TPM is basically, was first introduced in the year of 1970, as a unique
Japanese philosophy, which has been developed based on the concepts and methodologies of Productive Maintenance and its concept first introduced by M/s Nippon Denso Co. Ltd, while RCM was founded in the 1960s and initially oriented towards maintaining airplanes and used by aircraft manufacturers, the government and airlines.

There are many definitions of TPM and RCM had been described from various literature. TPM is an innovative approach to company maintenance that promotes autonomous maintenance between operators, eliminates faults through day-to-day activities involving the entire force work and optimizes equipment efficiency in order to maximise overall equipment effectiveness, OEE while RCM is a structured approach to blends failure and risk analysis with preventative and condition based maintenance, improving equipment reliability and ensures that only the maintenance that matters is carried out. TPM and RCM can be linked together because the tool used in RCM which is FMEA included together with TPM as a tool of Lean Manufacturing. Both have the same concept which wants to increase product quality, equipment reliability, increase safety, and reduce operation cost through waste elimination. Mostly TPM is described to be implemented in big plant industries while RCM can be applied in small or medium size plant. In nutshell, the result of the conceptual analysis is illustrated in Figure 15.
Questionnaire survey method is done and this survey involved all people from the top managements to the operator by using self-enumeration data collection method. In this method, the respondent completes the questionnaire without the assistance of an interviewer. The survey has been answered electronically (including the Internet). So, the survey is done using the application of Google Forms. Based on the survey result, most of the respondents come from Multi-National Corporation (MNC) with percentage of 57.1%. Question four asked about the Type of maintenance strategies used in an organization. From the result, most of the respondent comes from the companies that high implementing Preventive Maintenance and Corrective Maintenance rather than TPM and RCM. So, it is clear that most of the companies still used the traditional maintenance. Most of the respondent ranked their organization effectiveness maintenance strategies in a fair stage. As an addition, in future the analysis in this study can include continuous improvement together with RCM and TPM.

Figure 15: The relationship of TPM and RCM
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