Exploring Smart Reliability Centred Maintenance in Property Management

Chan K., HKSAR, China

Keywords: Reliability Centred Maintenance, property management, maintenance management, key success factors.

Summary

This research is to explore the effectiveness of smart application of Reliability Centred Maintenance (RCM) in property/maintenance management, supported by Hong Kong practical cases; whilst identifying the key success factors of RCM in this industry. Quantitative approach through predesigned questionnaire survey and qualitative approach via interviews for verifications with major stakeholders in the property management industry will be conducted to project a comprehensive investigation of the RCM issues to cast some lights for future advancements.

Exploring Smart Reliability Centred Maintenance in Property Management

Chan K., HKSAR, China

INTRODUCTION

Reyes-Picknell, J.V. (2012) contends that Reliability Centred Maintenance (RCM) is the process of determining the most effective maintenance approach. The goal of the philosophy is to provide the stated function of the facility, with the required reliability and availability at the lowest cost. RCM requires that maintenance decisions be based on maintenance requirements supported by sound technical and economic justification.

This is especially true for RCM where the consequences of failure can vary dramatically. For these systems a streamlined or intuitive RCM analysis process may be more appropriate. The streamlined approach uses the same principles as the rigorous, but recognizes that not all failure modes will be analyzed (Energy Law Journal, 2018).

Braglia, Castellano and Gallo (2019) opine that the primary RCM principles are:

1) RCM Acknowledges Design Limitations – Its objective is to maintain the inherent reliability of the equipment design, recognizing that changes in inherent reliability are the province of design rather than maintenance.

2) In addition, RCM recognizes that a difference often exists between the perceived design life and the intrinsic or actual design life, and addresses this through the age exploration process.

3) RCM Uses a logic tree to screen maintenance tasks – This provides a consistent approach to the maintenance of all kinds of equipment. (Figure 1).

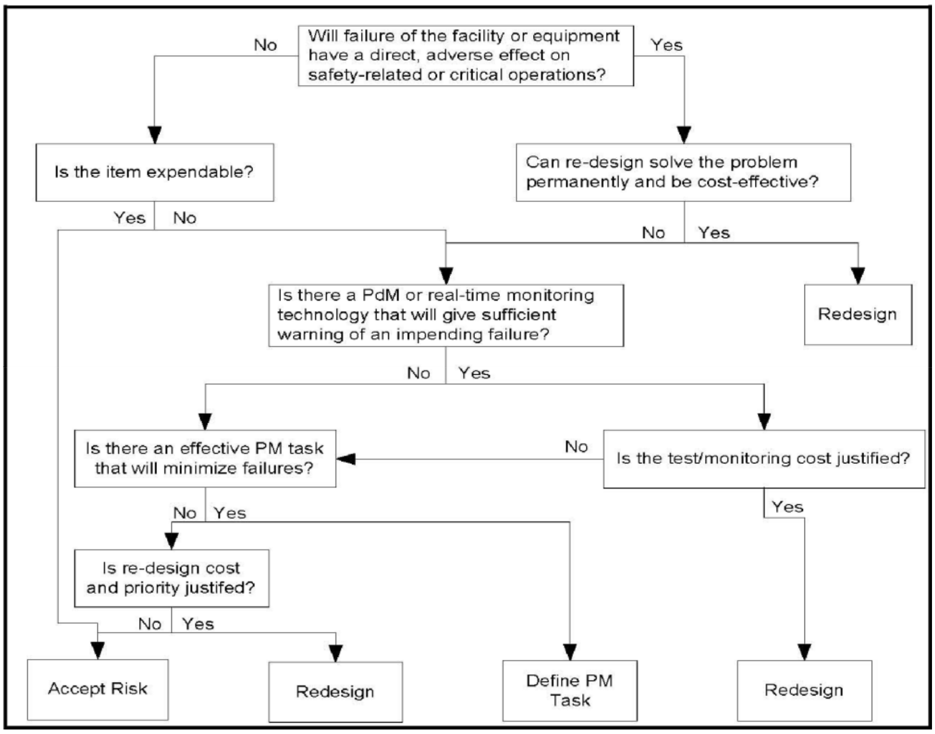

Figure 1 RCM Logic Tree

4) RCM acknowledges the following types of maintenance tasks

i. Time-directed – scheduled when appropriate
ii. Condition-directed (real-time monitoring) – performed when conditions indicate they are needed
iii. Failure finding (one of several aspects of proactive maintenance) – Equipment is run-to-failure. This is acceptable for some situations and some types of equipment.

Kong and Ekpiwhre (2019) state that RCM, however, requires us to look at failure from not just an equipment standpoint, but a system standpoint as well. A functional failure is essentially the inability of an item/system to meet its specified performance standard. The RCM goals are to identify the most cost-effective and applicable maintenance techniques to minimize the risk and impact of failure in facility and utility equipment and systems. To this end, it evolve the following outcomes from an RCM analysis:

i. This type of maintenance assumes that failure is equally likely to occur in any part, and that a failure is not detrimental to the operation.

ii. A purely maintenance program ignores many of the opportunities to influence equipment survivability.

iii. PM is also referred to as time-driven or interval-based maintenance.

iv. PM schedules inspection and maintenance at pre-defined intervals in an attempt to reduce equipment failures.

v. Perform Condition Based Maintenance (CBM) – CBM consists of Predictive Maintenance (PdM) and real-time monitoring. PdM primarily uses non-intrusive testing techniques to measure and trend equipment performance.

vi. CBM replaces arbitrarily timed maintenance tasks with maintenance that is scheduled only when warranted by equipment condition. Continuing analysis of equipment condition data allows for planning and scheduling maintenance activities or repairs prior to functional or catastrophic failure.

vii. In most cases adding redundancy eliminates the risk and adds very little to overall maintenance costs.

RCM affects all phases of the acquisition and operations stages to some degree. As RCM decisions are made later in the life cycle, it becomes more difficult to achieve the maximum possible benefit from the RCM program.

LITERATURE REVIEW

Liu et al (2019) explain that Reliability Centred Maintenance (RCM) recognizes that maintenance can do no more than ensure that physical assets continue to achieve their built-in capability or "inherent reliability". Initiatives outside maintenance (such as Just In Time in manufacturing, higher product quality requirements, increased awareness of workplace safety and more stringent environmental regulations) are placing increasing pressure on maintenance departments.

Blache (2009) justifies that reliability and maintainability is increasingly important in modern manufacturing plant - so much so that many world class companies are using RCM to maximize plant output whilst optimizing operating costs. RCM uses a structured framework to ask the following questions about the selected asset in its operating context:

i. What are the functions/associated performance standards of the asset?

ii. What causes each functional failure?

iii. In what way does each failure matter?

iv. What should be done if a suitable preventive task cannot be found?

A Functional Failure is defined as the inability of an item or component to meet its desired standards of performance. Hidden failures, which in themselves have no direct consequences but expose the organization to the risk of other (often serious) failures. Lynch (2019) define that Predictive and Preventive Tasks are adopted to use a highly developed decision algorithm, whilst each Failure Mode is analyzed to determine a suitable Predictive or Preventive Task. Maintenance people on their own cannot answer these questions posed by RCM. For this reason, "Review Groups" are established to apply RCM and hence determine the maintenance requirements of each asset. The seniority of the review group members (each of whom will require RCM training) is less important than their knowledge of the equipment under review. Moreover, greater safety and environmental protection are demanded due to:

i. improved maintenance of existing protective devices
ii. the systematic review of safety implications of every failure
iii. the application of clear strategies for preventing failure modes which can affect safety or infringe upon environmental regulations
iv. fewer failures caused by unnecessary maintenance

Hussan (2018) outlines that reduced life cycle costs can be achieved by optimizing the maintenance workloads and providing a clearer view of spares and staffing requirements. When applied correctly, it transforms both the maintenance requirements themselves and the way in which the maintenance function as a whole is perceived. Since many equipment failures have disastrous consequences, the basic RCM process developed was very formal and rigorous:

i. Define the major systems and components.
ii. Where systems are extremely complex and this complexity makes analysis difficult, the user may opt to define subsystems as a means of organizing the problem into manageable pieces.

Figure 2 presents a sample RCM analysis sheet (“RCM System Data Sheet”) that would be generated in applying a rigorous RCM analysis to a chilled water system supplying computer equipment. Figure 3 presents one of the sample Failure Mode Sheets that would be produced describing how one of the components of the chilled water system could fail.

In addition, Figure 3 is a breakout of one of the 12 distinct failure modes listed in Figure 2. In a formal and complete RCM analysis, 11 other Failure Mode Sheets such as listed in Figure 3 would be produced. Due to the extensive up-front effort involved in producing a formal RCM analysis, it is recommended that facilities only pursue this level of detail for those systems where the consequences of failure are catastrophic.

Building Chilled Water System			
Function	**Functional Failures**	**Failure Modes**	**Maintenance (M) or Operation (O)**
Provide chilled water at specified flow rate and temperature	Total loss of flow	Motor Failure	Both
		Pump Failure	Both
		Catastrophic Leak	M
		Blocked Line	M
		Valve out of position	Both
	Insufficient flow	Pump cavitation	O
		Drive problem	M
		Blocked line	M
		Valve out of position	Both
		Instrumentation	M
	Chilled water temperature too high	Chiller fatigue	Both
		Low refrigerant	M
		Fouled heat exchanger	M
		Instrumentation problem	M
		Cooling tower problem	M
		Valve out of position	Both

Figure 2 Sample RCM System Data Sheet

Electric Motor # 123456			
Function: To provide sufficient power to pump 300 gpm chilled water			
Component	**Functional Failure**	**Failure Mode**	**Source of Failure**
Stator	Motor will not turn	Insulation Failure	Insulation contamination Excessive current Voltage spike Phase imbalance Excessive temperature
		Open winding	
Rotor	Motor will not turn	Burnt rotor	Insulation contamination Excessive current Excessive temperature Imbalance
	Wrong speed	Excessive vibration	
Bearings	Motor will not turn	Bearing seized	Fatigue Improper lubrication Misalignment Imbalance Electrical pitting Contamination Excessive Thrust Excessive temperature
Motor Controller	Motor will not turn	Bearing seized	Mainline contact failure Control circuit failure Loss of electrical power Cabling failure
	Wrong speed	VFD malfunction	
Overloads/fuse	Motor will not turn	Device burned out	Excessive current Excessive torque Poor connection
Shaft/coupling	Pump will not turn	Shaft/coupling sheared	Fatigue Misalignment Excessive torque

Figure 3 Sample failure mode sheet

Due to the initial investment required to obtain the technological tools, training, equipment condition baselines, a new RCM program typically results in a short-term increase in maintenance costs (Figure 4). The net effect is a reduction of reactive maintenance and a reduction in total maintenance costs. The ability of a condition monitoring program to forecast certain maintenance activities provides time for planning, obtaining replacement parts, making the necessary logistical arrangements (i.e. notifying occupants of equipment downtime) before the maintenance is executed.

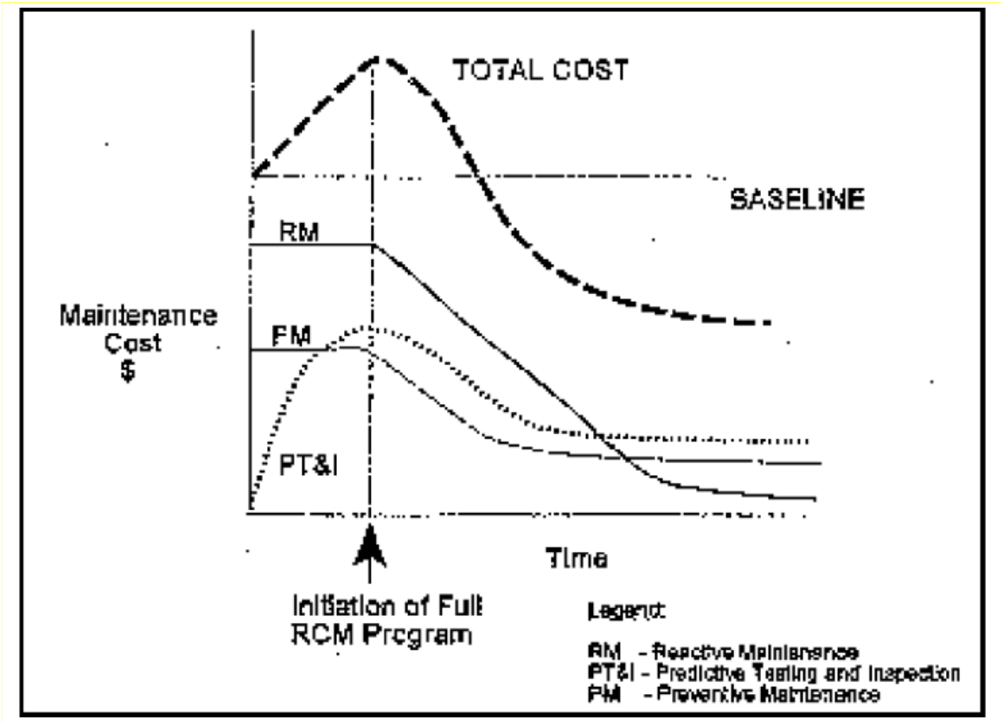

Figure 4 Maintenance Cost Trends under an RCM Program

Zhang (2018) interprets that this condition-based approach to maintenance extends the life of the facility and its equipment. Maintenance that is not cost-effective is identified and not performed. In summary, the multi-faceted RCM approach promotes the most efficient use of resources. The decision is best made during the planning phase. As RCM decisions are made later in the life cycle, it becomes more difficult to achieve the maximum possible benefits from the RCM program. While these operations and maintenance (O&M) savings may not be the majority of the facility’s life cycle cost, they are still a significant portion of the yearly operating costs of a facility, and would be well appreciated by any fiscal manager looking to cut operating costs. The disadvantages of outsourcing may include the followings:

i. A possible loss of flexibility in reacting to changing business conditions, lack of internal and external customer focus and sharing cost savings may also be a disadvantage of outsourcing.
ii. Thus the company may loose control over its process.
iii. Other disadvantages of outsourcing may include unfavourable contract lengths, loss of competitive edge, problems in contract renewal, and contractual misunderstandings.

Tsarouhas (2018) relates that a Failure Mode Effects and Critically Analysis (FMECA) evaluates, documents, and ranks the potential impact of each functional and hardware failure with focus on has on mission success, personnel safety, system performance, maintainability, and maintenance requirements. The following Figure 5 shows the Selection Logic diagram used to determinate significant functions and non-significant functions.

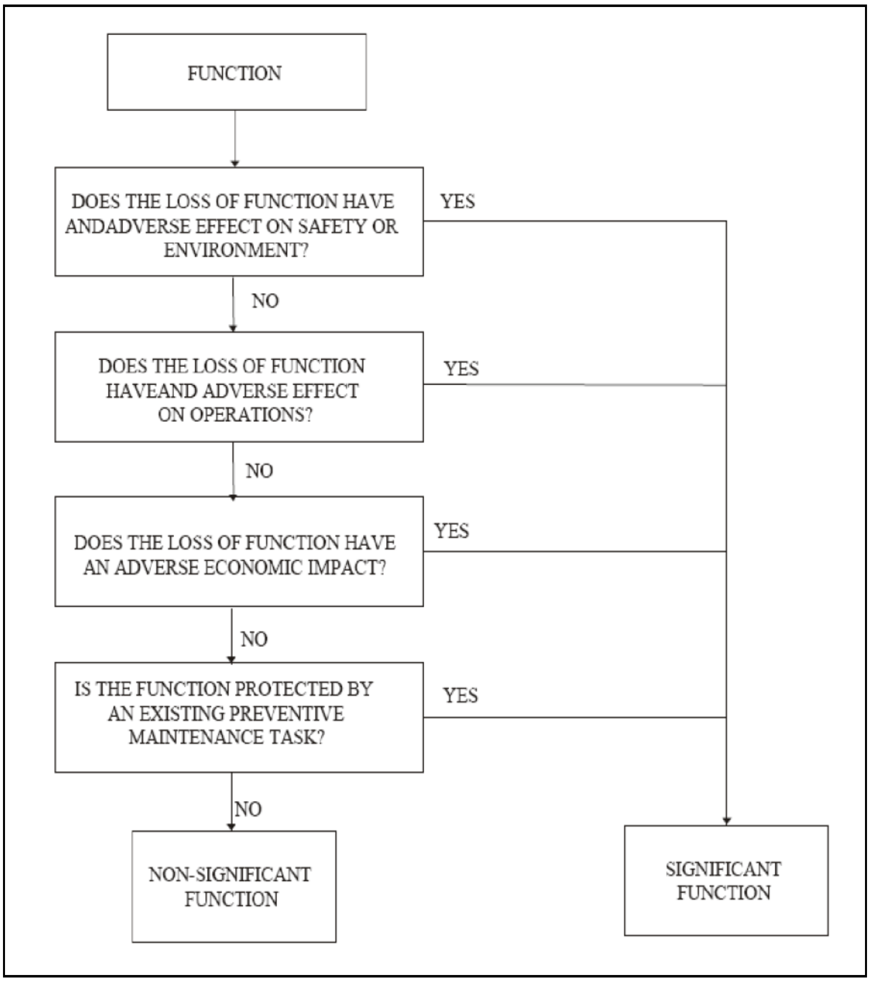

Figure 5 Selection Logic Diagram

The significant functions that were identified by the SF Selection Logic undergo further analysis as they are subjected to the RCM Decision Logic (Figure 5). Every function has one or more failure modes, whilst the Decision Logic consists of:

i. Evident Economic/Operational Consequences.

ii. Hidden Safety/Environmental Consequences.

When safety is involved, the functional failure must be prevented either by a Property Management (PM) task or some other action. The economic aspect is very important because of the colossal budget which must be used efficiently. The improvement of the maintenance function is the guarantee of the durability of the infrastructures and equipment. Turning to the PM department, the effectiveness of a system will finally be measured as follows (Figure 6):

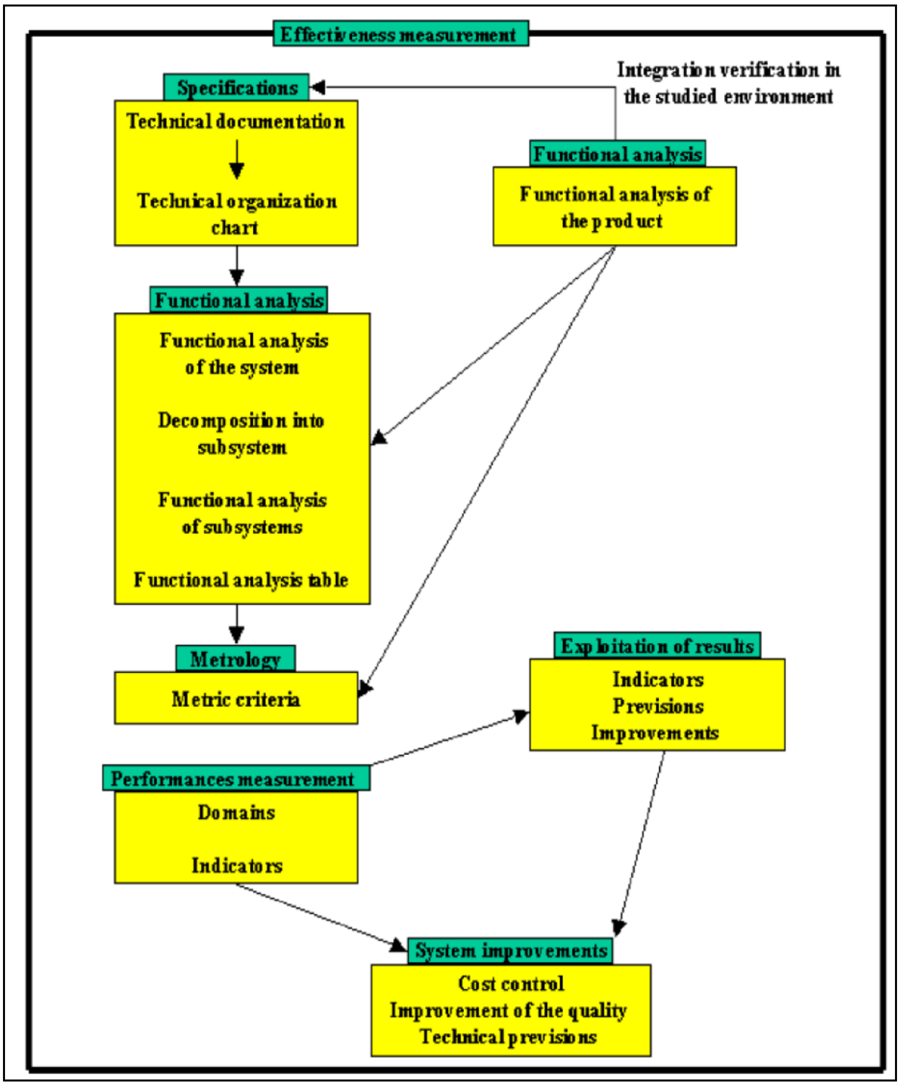

Figure 6 Effectiveness Measurement

METHODOLOGY

A well structured questionnaire is prepared (as reflected in the questions attached) for dispatching to major stakeholders e.g. senior management, property managers, maintenance managers, technical officers for returning answers within 2 weeks through random sampling from the major 1600 property management organizations in Hong Kong. A pre-test will also be done to verify if there may be problems in the questionnaire. Upon receive of these primary data, statistical analysis and tabulations will be performed.; with graphical presentations. Furthermore, with concepts of triangulation approach, in-depth interviews with relevant property management personnel will be done too.

The questionnaire is designed to covers areas regarding screener, maintenance, equipment control, maintenance works, stock upkeep, purchase, filing and decision making. Questions 1, 2, 3 are used to understand the workforce dedicated to maintenance, type of maintenance performs in-house or subcontract and sharing of maintenance in total operating cost. Questions 4, 5 are used to understand the equipment failure rate, operation losses and the preventive percentage of breakdown. Questions 6, 7, 8 are used to understand the documentation work for maintenance is adequate, how to plan for preventive maintenance and percentage of losses of breakdown etc. Questions 9, 10 are mainly engaged to understand the turnover rate of stocks, performed an optimization of spare parts or stock. Questions 11, 12 are principally adopted to understand the availability of historical record of maintenance, does maintenance team meet to analyse this historical record and adjust maintenance plans.

FINDINGS AND ANALYSIS

42 responses have been received out of 1600 PM organizations invited, which are discussed below. The return rate seems a bit less, bearing the usual apathetic situation of researching in Hong Kong, it is considered acceptable for initiating such kind of research to pave way for further research in future.

Question 1 verifies that all respondents are the major stakeholders in this property management industry, where 79% respondents committed to maintenance works. From Question 2 (Table 1), 52% of respondents perform condition-based maintenance in-house. Condition Based Maintenance is a system that uses real-time data to prioritize and optimize maintenance resources. That system will determine the equipment's health, and act only when maintenance is actually necessary.

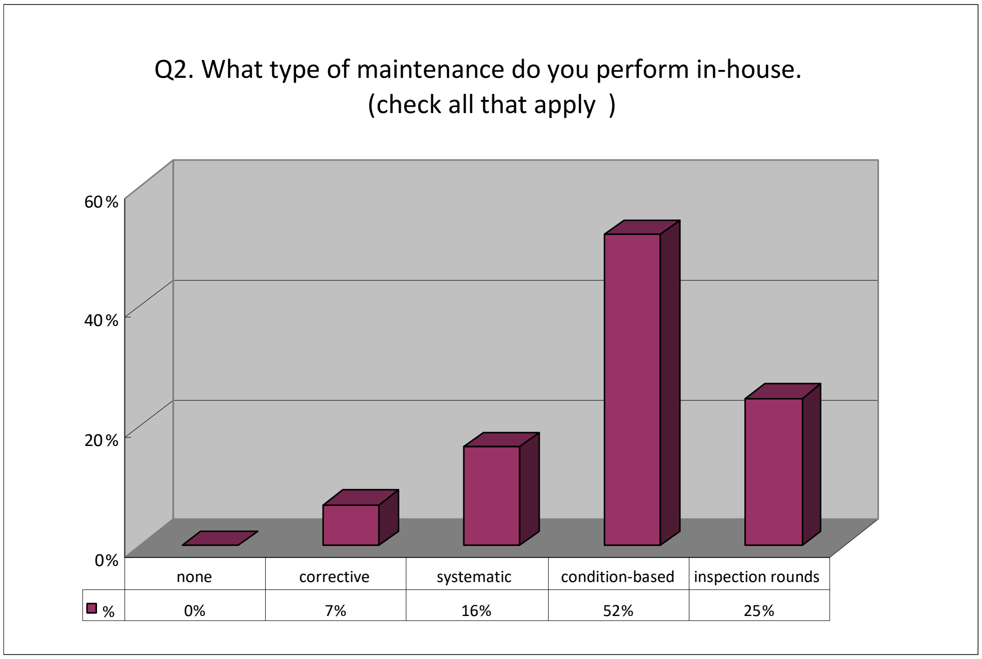

Table 1 Type of Maintenance Perform In-house

From Question 3 (Table 2), majority 86 % of total operating cost goes to maintenance.

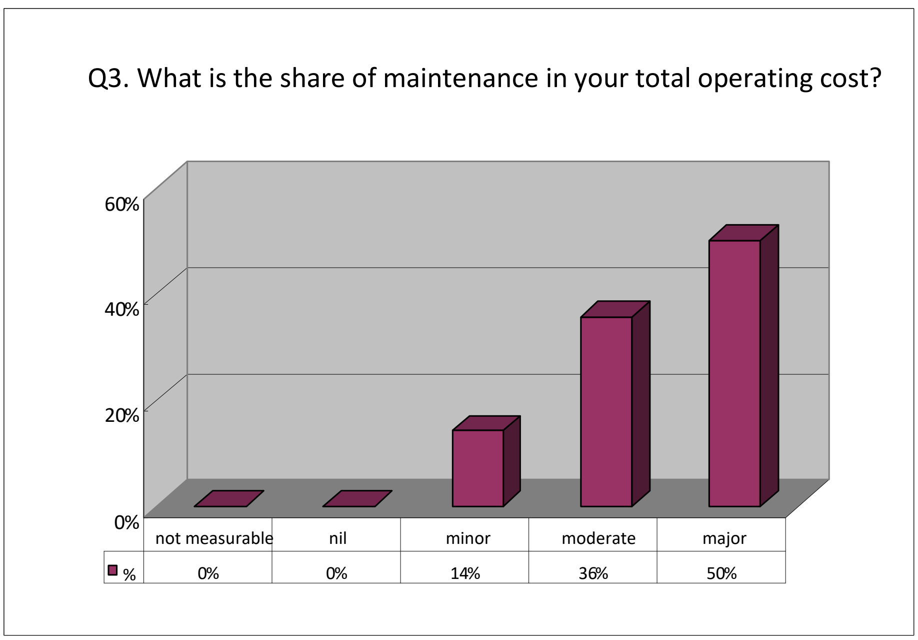

Table 2 Share of Maintenance in Total Operating Cost

From the above findings, it reveal that the workforce is dedicated to maintenance with a very high percentage but preventive action of overall maintenance is relatively low. The corrective and systematic maintenance subcontract rate are high comparatively with condition-based and inspection rounds, it emphasis most maintenance services are subcontracted but not balanced with the condition-based and inspection rounds maintenance. That means the need of performing in-house maintenance of condition-based and inspection rounds are significant. Closer monitoring and supervising work are important to lower the overall maintenance cost.

From Question 4 (Table 3), 86% respondents opine that only some equipments got failure.

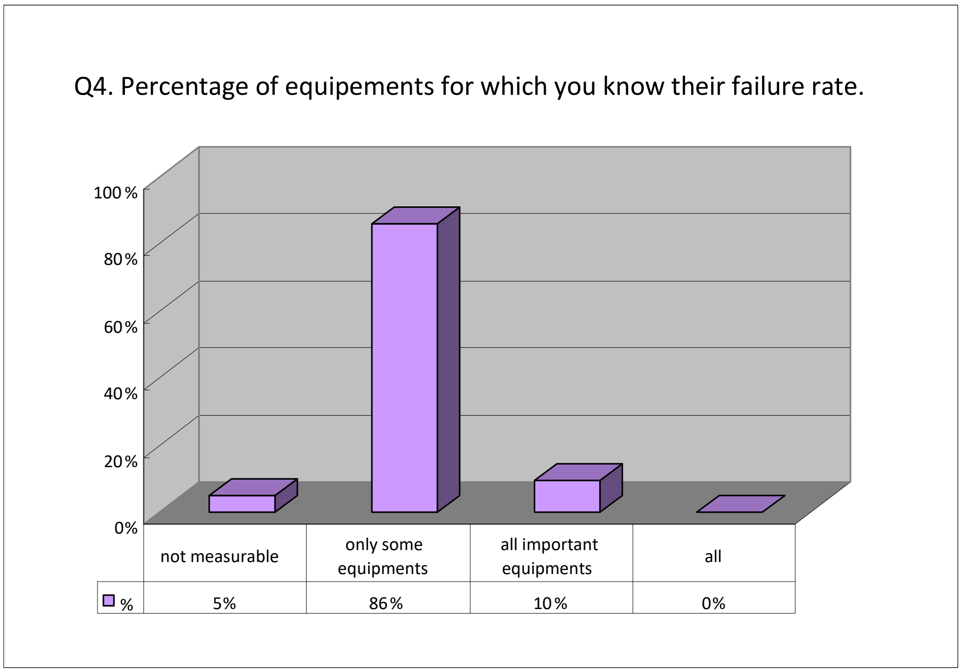

Table 3 Percentage of equipment for which you know their failure rate

From Question 5 (Table 4), 86% majority failed important equipments resulting in operation losses.

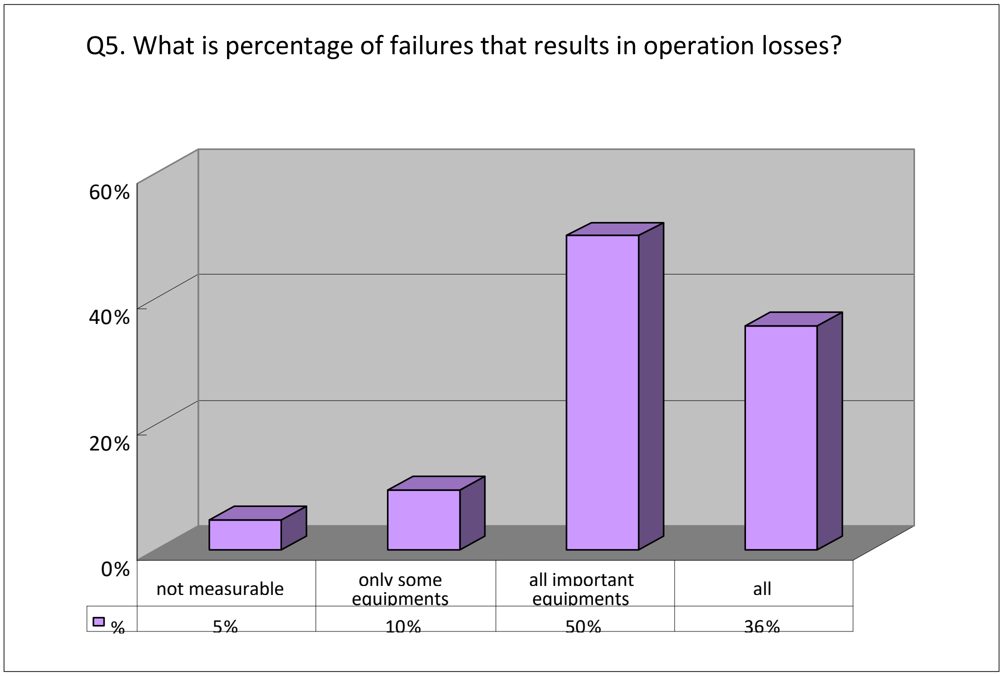

Table 4 Failure that results in operating losses

The above findings demonstrate that there is very high percentage of some equipment failure which requires improvement. Over 80% of all equipment are in a poor condition leading to disruptions of operations; while 50% of result in operation losses.

From Question 6 (Table 5), 81% of the available documentation collectively go to maintenance record, work orders, and preventive maintenance plans, to allow for preparing/caring out maintenance tasks.

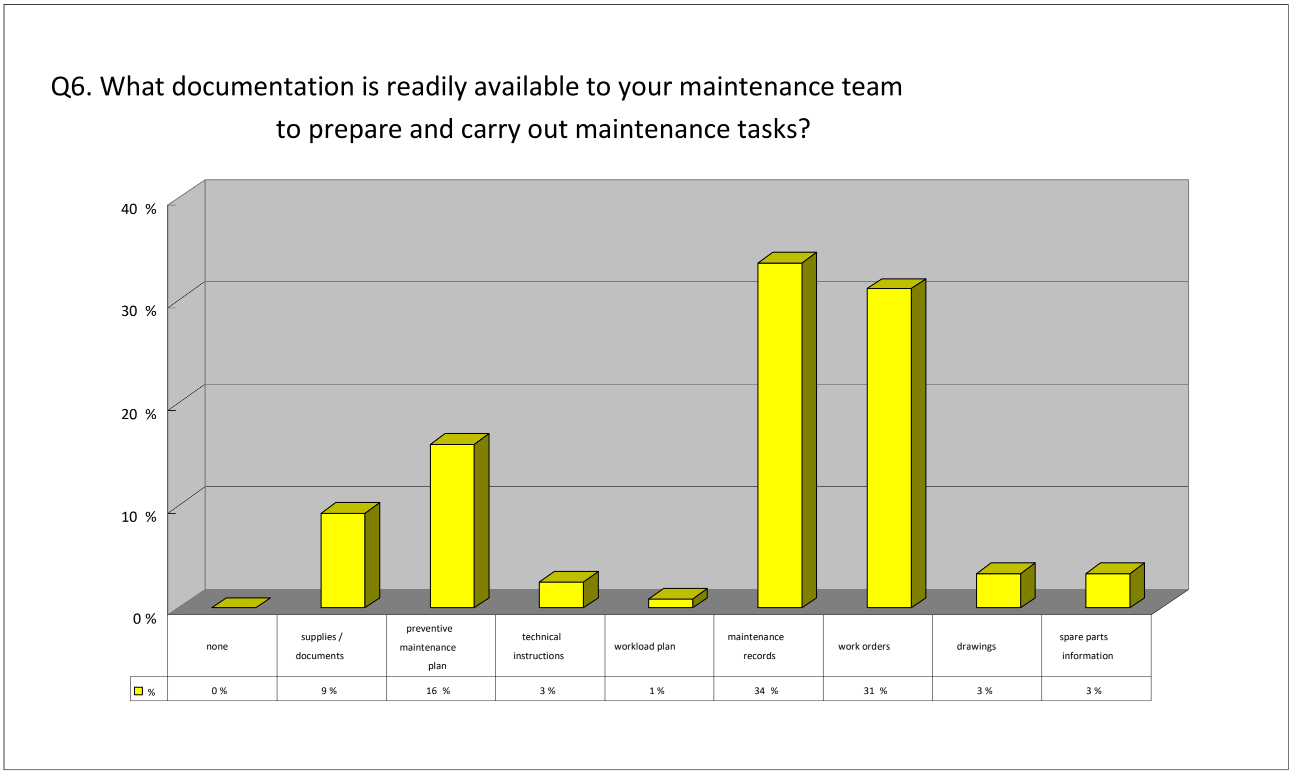

Table 5 Documentation is available to prepare and carry out maintenance tasks

From Question 7 (Table 6), there is 26% respondents opine 30% to 50% operation losses, whilst 45% opine 50% losses, and 26% conclude 26% losses not measurable. The situation is rather worse.

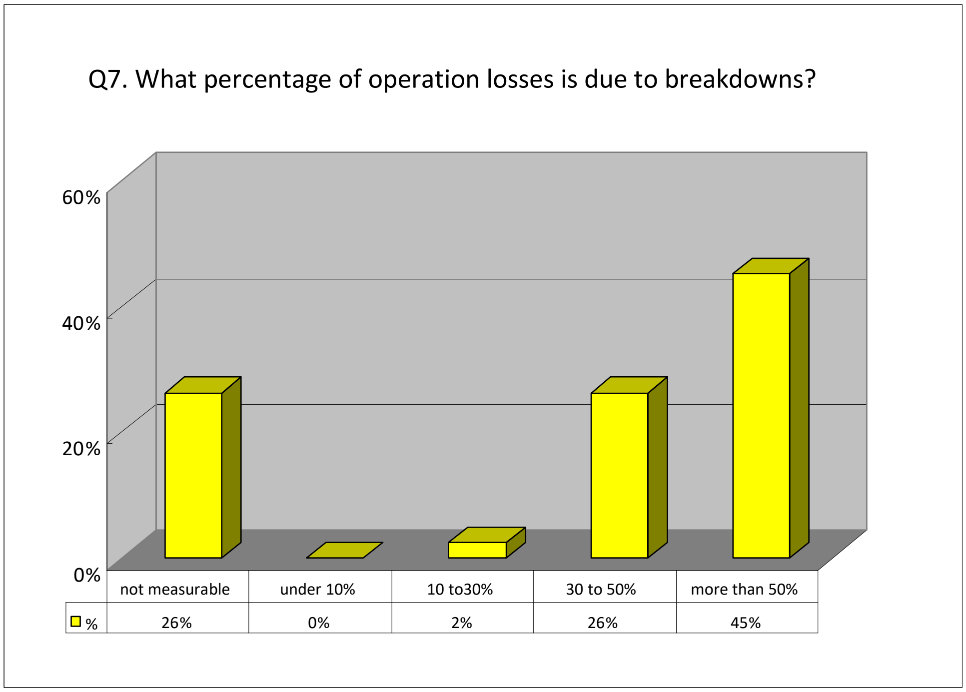

Table 6 Percentage of operation losses is due to breakdowns

From Question 8 (Table 7), about 65% respondents contend that the stoppages due to preventive maintenance are unsatisfactory/not very satisfactory.

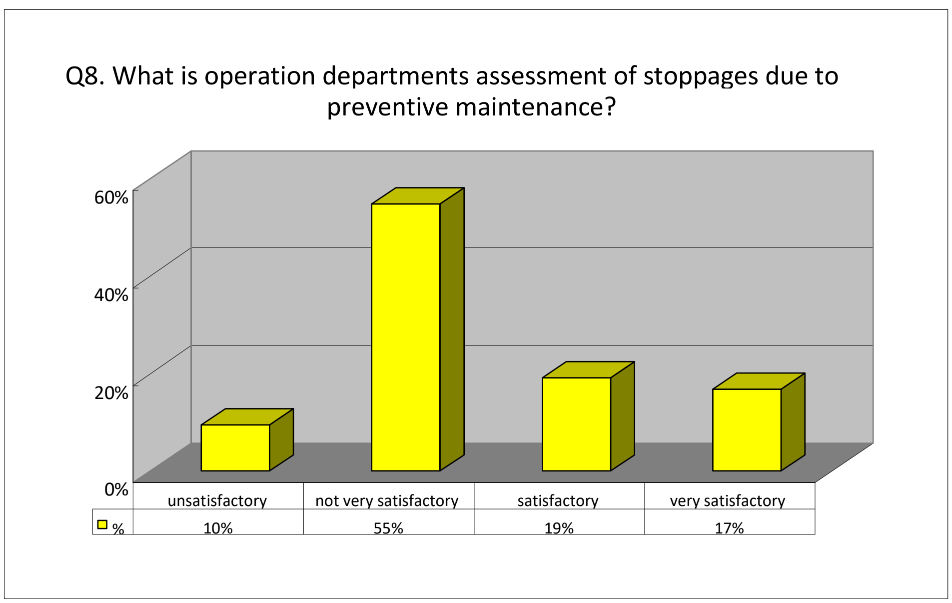

Table 7 Assessment of stoppages due to preventive maintenance

From the above findings, high percentage of maintenance records and work orders are available to help carry out maintenance tasks, yet other documentation such as supplies documents, technical instructions workload plan, drawings and spare parts information are minimal; whilst the preventive maintenance plan are not adequate for supporting maintenance task. There is high percentage indicating the operation losses owing to some more breakdowns. Most respondents are not very satisfactory on the stoppages due to preventive, whereby proper organizing preventive maintenance plan is crucial.

From Question 9 (Table 8), the majority, 21% respondents opine 25% to 50% stocks available for maintenance and 74% opine more than 50% stocks available.

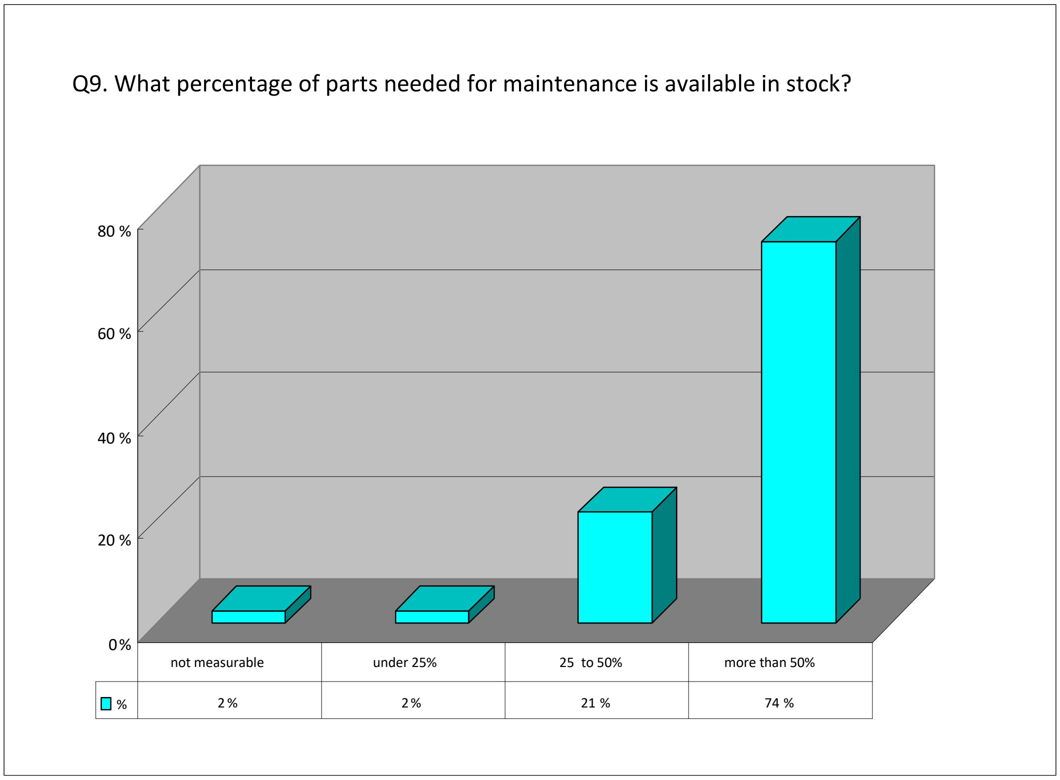

Table 8 Parts needed for maintenance is available in stock

From Question 10 (Table 9), 93% respondents recognize “good and tight” in control procedures for the origin and quality of spares.

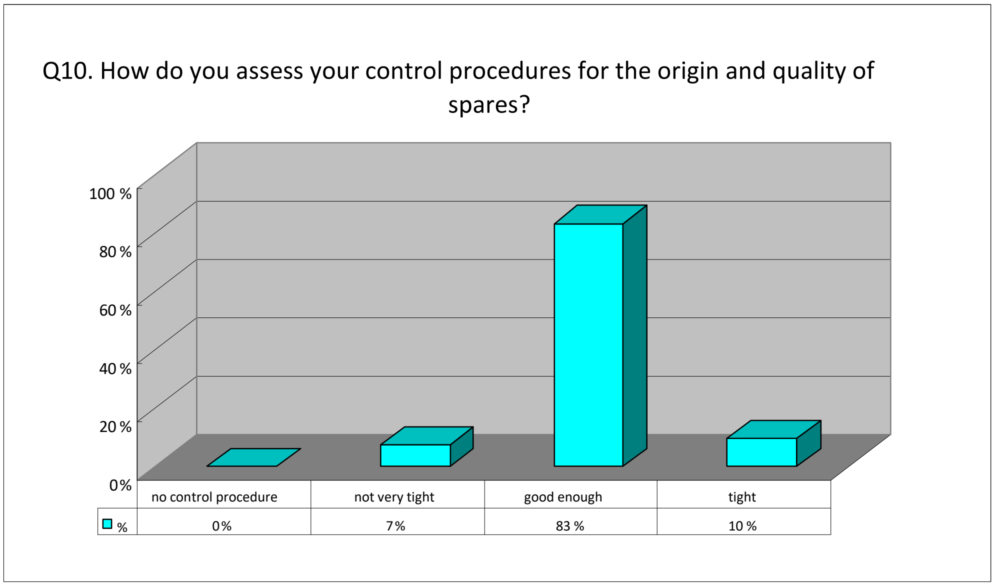

Table 9 Assess control procedures for origin and quality of spares

It is perceived that the turnover rate of spare parts/stock and optimum performance are not adequate, whilst the accessories for maintenance is relatively adequate in stock, and the control procedures for the origin and quality of spares are above good. In this instance, stock keeping/purchase control shall be improved systematically.

From Question 11 (Table 10) 64% respondent opine “randomly” for the maintenance team to meet in analyzing the historical record.

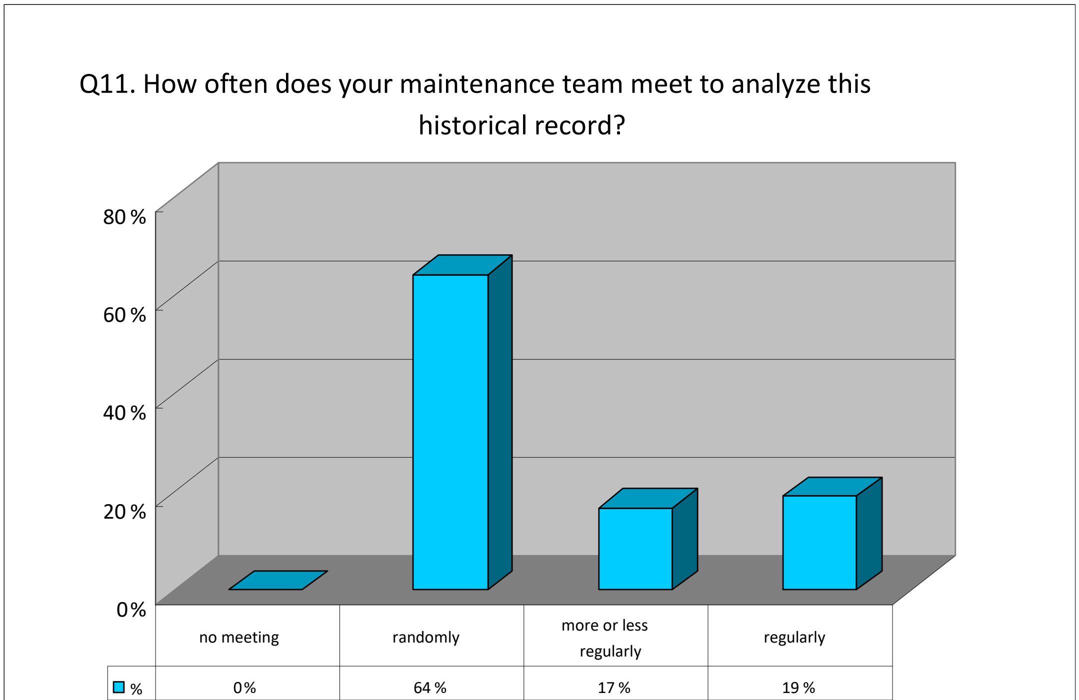

Table 10 Analyze the historical record

From Question 12 (Table 11) 62% respondents indicate "Yes but very partially" whilst 31% indicate "Yes but not comprehensively" for this analysis process allowing maintenance staff to compare the cost of various maintenance decision.

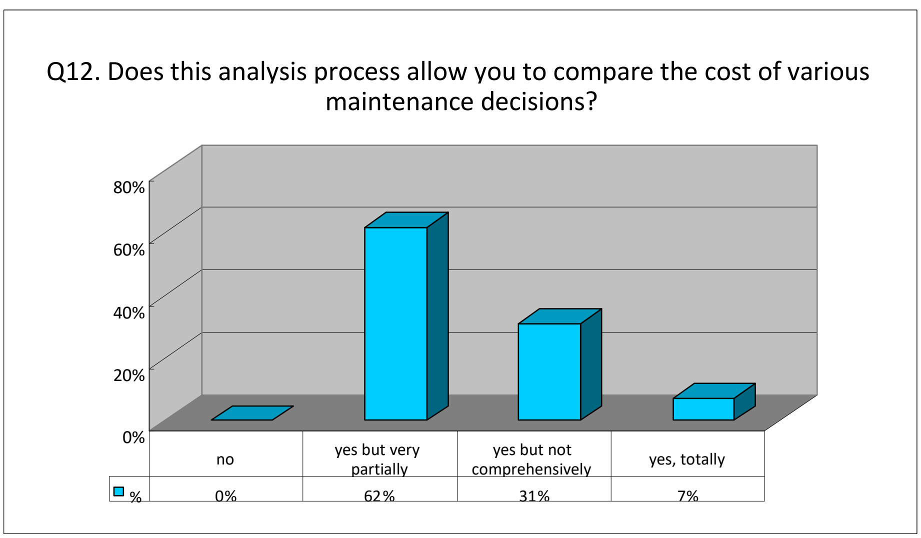

Table 11 Compare cost of various maintenance decision

The above findings illustrate that the historical record, analysis process, cost of various maintenance comparison are "not very satisfactory", therefore, investigation of implementing RCM in maintenance management is recommended.

CONCLUSION

Management of maintenance activities for various crucial facilities is a complex and expensive task. For some non-critical, inexpensive, and easily replaced components, run-to-failure method may be an acceptable practice. Maintenance to maximize service life of equipment or components and surveillance of performance degradation can allow repairs/replacement without interruption of mission-critical activities.

In spite of being a standardized approach, RCM can be adapted to particular constraints and requirements. There are various software tools help apply RCM for better capitalisation and reliability data management. Some analysis models of risk/simulations can also be used when implementing RCM. Yet, obtaining consistent un-manipulated data for measurements might be a major problem for the RCM toolkit. All RCM toolkits engage a database to organize its information to minimize redundant effort.

It is hoped that the captioned research will cast some lights on adopting RCM in better property/maintenance management in terms of better controls in finance, quality, resources and competitive edges to achieve organizational objectives.

REFERENCE

Anonymous (2018), REPORT OF THE OIL AND LIQUIDS COMMITTEE, ***Energy Law Journal***, Washington Vol. 39, Iss. 2, (2018): 1-32.

Blache, K.M. (2009), Slow movement toward predictive maintenance seen in Tennessee study, ***Plant Engineering***, Barrington Vol. 63, Iss. 6, (Jun 2009): n/a.

Braglia, M., Castellano, D., and Gallo, M. (2019), A novel operational approach to equipment maintenance: TPM and RCM jointly at work, ***Journal of Quality in Maintenance Engineering,*** Bradford Vol. 25, Iss. 4, (2019): 612
634. DOI:10.1108/JQME-05-2016-0018

Kong, F.T., Ekpiwhre, E. (2019), Reliability-based preventive maintenance strategies of road junction systems, ***The International Journal of Quality & Reliability Management***, Bradford Vol. 36, Iss. 5, (2019): 752-781. DOI:10.1108/IJQRM-01-2018-0018.

Hussan S.A. (2018), Life cycle cost analysis of the ventilation system in Stockholm's road tunnels, ***Journal of Quality in Maintenance Engineering,***
Bradford Vol. 24, Iss. 3, (2018): 358-375. DOI:10.1108/JQME-05-2017-0032.

Liu, Z., Liu, X., Liang H.Z. and Zhongwei (2019), A new inherent reliability modeling and analysis method based on imprecise Dirichlet model for machine tool spindle, ***Annals of Operations Research,*** New York (Aug 2019): 1-16. DOI:10.1007/s10479-019-03333-9.

Lynch, M. (2019), Monitoring Time for Preventive Maintenance Tasks, ***Modern Machine Shop,*** Cincinnati Vol. 92, Iss. 1, (Jun 2019): 34,36.

Reyes-Picknell, J.V. (2012), RCM a 'resource-consuming monster'? No, ***PEM: Plant Engineering and Maintenance,*** Oakville Vol. 35, Iss. 6, (Nov/Dec 2012): 34.

Tsarouhas, P. (2018), Reliability, availability and maintainability (RAM) analysis for wine packaging production line, ***The International Journal of Quality & Reliability Management,*** Bradford Vol. 35, Iss. 3, (2018): 821-842. DOI:10.1108/IJQRM-02-2017-0026.

Zhang, T. (2018), The three levels of condition-based maintenance, ***Plant Engineering,*** Barrington Vol. 72, Iss. 4, (May 2018): 5-6, 8.