

FRAMEWORK FOR ENSURING EFFECTIVENESS OF MAINTENANCE IN BUILDING SERVICES

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ABSTRACT

Maintenance management of building services has become one of the critical issues among building sector professionals recently. The interruptions or damages to the building services extensively affect the core operation of the business. Therefore, appropriate maintenance management arrangements are required to sustain a proper building services system. Building practitioners tackle various issues and seek a variety of alternative solutions to deliver an effective maintenance strategy for the building services. However, the lack of consideration on the overall effectiveness of maintenance services has faced frequent problems such as human errors, health and safety issues, resource scarcities, and time delays. In order to address those problems, this research has been carried to develop a framework that ensures the effectiveness of maintenance activities of the building services in Sri Lanka.

An extensive literature review was mainly carried to discover the impact of effective maintenance activities towards the building services. Afterwards, a preliminary experts' survey was conducted to obtain the factors affecting to effectiveness of maintenance activities. Subsequently, a questionnaire survey was conducted among maintenance personals to rank identified factors according to their impact. Further, semi-structured interviews have been carried out mainly to identify the limitations of maintenance work.

The framework highlights the factors that affect the effectiveness of maintenance activities of building services. Further, the framework facilitates to address the limitations of maintenance activities of building services. The framework can be used as clear evidence to convince both top management and owners of organisations to ensure the effectiveness of maintenance activities as well.

Keywords: *Building Services; Commercial Buildings; Effectiveness; Maintenance Activities; Maintenance Staff*

1. INTRODUCTION

Maintenance management of building services has become one of the essential functions that enriches the building and organisational performance. Inappropriate maintenance and operation of the building services liable for the high percentage of unnecessary energy consumption of (Wu *et al.*, 2010) and poor building performance. Mainly, building services provides warmth, power, security, light, air quality, water, sound control, transport, communication and sanitation for buildings in order to provide safe and healthy living or working environment for both people and processes (John *et al.*, 2005). However, the functionality of these systems is doubtful, without an appropriate and effective maintenance management system. Effective maintenance management plays a significant role to achieve organisational goals by enhancing the overall efficiency of building services (Abreu *et al.*, 2013). Accordingly, appropriate and sufficient maintenance events are required in order to minimize the plant failures and to enhance the reliability of machineries (Wang, 2012).

Numerous problems such as communication and attitudes in between operations and maintenance process impede the effective maintenance functions (Jonsson, 1997). Various authors have suggested appropriate steps, sequences and practices to manage maintenance activities (Marquez *et al.*, 2009) effectively by addressing those problems. Mishra *et al.* (cited Marquez *et al.*, 2009) noted that there should be an ideal

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model for building services maintenance activities in order to achieve the efficient and effective maintenance activities accomplishing organisational objectives. The authors developed a framework for maintenance management, which has not entirely covered the area in terms of effectiveness of maintenance activities except some techniques such as Balance score card, Criticality analysis and Failure root cause analysis which can be used to measure the effectiveness of maintenance activities. Nevertheless, there is no proper guidance to improve the overall effectiveness of maintenance activities of building services. The lack of knowledge and consideration regarding overall effectiveness of maintenance activities in building services was encouraged to address in this research. Accordingly, the aim of this research is to develop a framework that ensures the effectiveness of maintenance activities of building services. The following objectives are set to achieve the aim of this research.

1. Recognize the impact of effectiveness of maintenance activities in building services,
2. Identify the existing factors affecting the effectiveness of maintenance activities of building services,
3. Investigate the limitations prevailing within maintenance management.

2. LITERATURE REVIEW

2.1. MAINTENANCE MANAGEMENT

Maintenance is one of the most essential expenditure and major cost reduction programme in the operating budget (Tsang, 2002). Panchdhari (2003) defined maintenance as the effort which carries out to retain, restore or enhance every-facility within each part of building, services and surroundings of the building to tolerate facility's utility values and presently-accepted standards. Thus, maintenance can be identified as an important support function in an organisation for which invests significant physical assets in order to achieve organisational goals (Obiajunwa, 2013).

Since, maintenance contributes to the security of the process, return on investment control, performance enhancement, solid image and interpersonal relationships of the organisations, industries have given considerable attention towards maintenance activities (Abreu *et al.*, 2013). Mobley (Pun *et al.* 2002) explained that in most situations, maintenance is required to achieve organisation's maximum profitability. Similarly, maintenance activities can be able to add value to business processes using ISO 14001:1996 and ISO 9001:2000 Standards (Bamber *et al.*, 2004).

The approach towards the maintenance has changed considerably throughout the last century. Yam *et al.* (2000) mentioned that several types of maintenance strategies such as equipment failure-driven, time-based, condition-based preventive, reliability centered and proactive type maintenances are introduced recently. In general, to enhance the effectiveness of maintenance activities some maintenance approaches such as Total Productive Maintenance (TPM), Reliability Centered Maintenance (RCM), Profit Centered Maintenance and Proactive Maintenance would be helpful for any type of organisation (Pun *et al.*, 2002).

2.2. MAINTENANCE MANAGEMENT IN BUILDING SERVICES

Building service systems are installed to support the requisite business functions such as mechanical, security, safety, electrical, communication and information systems (Wu *et al.*, 2010). The building services systems include lighting, air conditioning, electricity, gas supply, fire protection and detection, vertical transportation, water supply and drainage and other numerous installations such as waste disposal systems, external wall access, cleaning facilities and building automation systems (Yik and Lai, 2005). Wu *et al.* (2010) stated that maintenance is still required for building services systems to fulfil user requirements, even though these systems perform well as per manufacturers' perspective. Generally, buildings will not be valuable assets without proper operations and maintenance. Therefore, to preserve aesthetic appearance, water-tightness and structural integrity, maintenance is required. Moreover, without having proper operations and maintenance of building services, tenant complaints, unnecessary energy consumption and environmental damages (reducing indoor air quality) can be occurred (Wu *et al.*, 2010). It is required to conduct operations and maintenance function for building services systems in order to

keep proper environmental condition inside the building without reducing the quality of the facilities given to the occupants (Yik and Lai, 2005).

2.3. ISSUES ASSOCIATED WITH MAINTENANCE ACTIVITIES

The lack consideration on maintenance activities has been highlighted recently, as managers ignored the relationship between profitability and maintenance properly (Jonsson, 1997). The communication gap between the persons who control the technical aspects and the persons who control the financial aspects of maintenance has created adversarial influence on maintenance practices (Mostafa, 2004).

Abreu *et al.* (2013) identified several issues in maintenance management, such as deficiency of maintenance reporting with respect to local and corporate perception and deficiency of action improvements with respect to business process. The authors further stated that maintenance shall not consider as a “poor relative” to the organisation and only considered as some source of expense to the organisation. Au-Yong *et al.* (2014) stated that poor knowledge and skill of labours is a major barrier that affects the effectiveness of maintenance management. Moreover, Lind and Muyingo (2012) argued that the maintenance budget allocation may not always be enough for the maintenance operation. Further, Jonsson (1997) explained that, many organisations establish only a few goals for maintenance activities, although goals and strategies are required to achieve the effectiveness of maintenance activities.

2.4. EFFECTIVENESS OF MAINTENANCE ACTIVITIES

Various authors have proposed approaches that evaluate the performance of maintenance to improve its effectiveness (Aoudia *et al.*, 2008). Marquez *et al.* (2009) explained that effectiveness indicates how well a function or department meets its company needs or goals, and is frequently conversed regarding service provided quality in the customer’s perspective. Further, effectiveness focuses on required outcome and the accuracy of the process. Moubray (cited Ahuja and Khamba, 2008) mentioned that the effective incorporation of maintenance activity with engineering activity in the organisation, supports to save numerous useful resources such as time and money in dealing with maintainability, reliability, performance issues and availability.

In the past, maintenance have considered on equipment’s aspects rather than human aspects. But, Effective Centred Maintenance (ECM) mainly focuses on customer’s aspect and consists with several features which improves the performance of maintenance activities (Pun *et al.*, 2002). According to Wang and Hwang (2004) allocating optimal combination of maintenance cycle and maintenance personnel would supports to determine the efficient and effective maintenance plans and schedules.

Moreover, Campbell (cited Zhu *et al.* 2002) explained that maintenance process should be able to retain assets in a predetermined operating condition to satisfy the primary business process. Similarly, Kelly (cited Zhu *et al.* 2002) mentioned that the interrelationship between primary processes and the maintenance process is necessary in order to meet effective maintenance management. Sherwin (2000) suggested that proper resources’ deployment, form of maintenance materials and spare parts, manpower, necessary instruments and tools and organisational life cycle profit are the significant factors which affect the effectiveness of maintenance management.

Jonsson, (1997) presented a model of five linked maintenance management components as strategy, human aspects, support mechanisms, tools/techniques and organisation Further, the author stated that the effectiveness of maintenance management policy, highly depends on the soundness of each above elements and their individual effectiveness. Sherwin (2000) mentioned that every maintenance activity should be fully documented in order to collect information regarding the operation, maintenance, modifications, failures and cost associated with each machineries and equipment. In addition, most of maintenance management failures have occurred since the absence of management commitment towards maintenance activities rather than lack of concepts or techniques (Bamber *et al.*, 2004). The effectiveness of maintenance activities highly depends on problems of communication and attitudes between maintenance and operations (Jonsson, 1997). Similarly, various authors have highlighted a variety of factors that affect the effectiveness of maintenance activities.

Table 1 comprise the factors identified through journals and books in relation to the effectiveness of maintenance activities. Since Table 1 basis for the final framework, factors affecting to effectiveness of maintenance activities have been gathered by considering common maintenance activities related to building services. In addition, most of those factors have been justified in terms of authors' perspective.

Table 1: Effectiveness of Maintenance Activities: Literature Findings

Author(s) Name	Yam <i>et al.</i> , 2000	Jonsson, 1997	Sherwin, 2000	Bamber <i>et al.</i> , 2004	Ben-Daya <i>et al.</i> , 2009	Pintelon <i>et al.</i> , 1999	Horner <i>et al.</i> , 1997	Lewis <i>et al.</i> , 2011	Tsang, 2002	Al-Ghanim, 2003	Wang and Hwang, 2004	Mostafa, 2004	Au-Yong <i>et al.</i> , 2014	Allen, 1993	Reis <i>et al.</i> , 2009	Tam and Price, 2008	Ali and Mohamad, 2009
Attitude and Communication Problem	×																
Proper Documentations			×	×									×				
Manager's Commitment	×	×	×														
Equipment history file					×												
Information Technology						×											
Spare Part Inventory	×				×	×	×			×			×				
Outage Control	×																
Human Resource Management/man power	×						×										
Maintenance Organisation's Structure	×																
CMMS								×									
Service Delivery Options									×								
Periodic Maintenance			×							×							
Legal Regulations			×														
Personnel Competencies										×							
Equipment Handling											×						
Staff Trainings												×			×		
Level of Sophistication of the tools													×				
Frequency of Inspection and Monitoring													×				
Maintenance Audit														×			×
Prioritization																×	

3. RESEARCH METHODOLOGY

An extensive literature review was conducted to identify the maintenance activities of building services, the effectiveness of maintenance activities and factors that affect to ensure effectiveness of maintenance activities of building services respectively. The aim of this research is to develop a framework to ensure the effectiveness of maintenance activities. Considering the nature of this research, mixed methods research approach was used.

Firstly, the preliminary expert survey was carried out as semi structured interviews among four maintenance managers, who have more than 10 years' experience in the maintenance field in commercial buildings. During the expert survey, the relevance and importance of ensuring the effectiveness of maintenance activities of building services were discussed in order to ensure the practicability of the aforementioned factors in the Sri Lankan context. In addition, personal opinions and comments of experts regarding the nature of maintenance operations in their organisation were discussed. Subsequently, a questionnaire was developed based on the findings from the preliminary survey. The main objective of the questionnaire survey is to identify the criticality of factors which are affecting to maintenance activities of building services. Therefore, these fixed response types' questionnaires along with provisions

for comments were distributed among a judgmental sample of maintenance staff members in the commercial building sector. In addition, a semi structured interview survey was carried out to attain the fourth objective of this study. The study selected 12 persons who are currently working in the maintenance field to identify the most common limitations available in the maintenance field.

In this research content analysis technique was used to analyse the data gathered from semi-structured interviews. In addition, NVIVO software was also used to carry out content analysis. In order to rank the criticality of the factors RII method was applied since it indicates the level of significance of a particular factor through the given questionnaires. For that following formula was used.

$$\text{Relative Important Index} = \frac{\sum wn}{AN} \times 100\% \quad (\text{Eq. 01})$$

Where, W is the weighting given to each factor by the respondent, ranging from 1 to 5, n is the frequency of responses, A is the highest weight and N is the total number of samples.

4. RESEARCH FINDINGS

4.1. PRELIMINARY EXPERT SURVEY

Collected data was analysed under following two broad headings:

- Overview of maintenance activities of building services, and
- Effectiveness of maintenance activities.

4.1.1. OVERVIEW OF MAINTENANCE ACTIVITIES OF BUILDING SERVICES

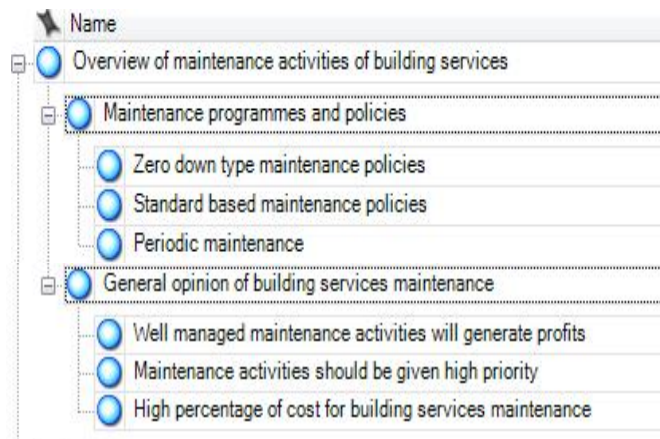


Figure 1: Overview of Maintenance Activities

The initial step was to obtain the information on existing building services maintenance activities. Thus, the interviewees were questioned on their general opinions and experiences on maintenance activities of building services. Accordingly, NVIVO software was supported to categorise received data into two sections as in Figure 1. Overview of maintenance activities of building services is discussed with the general opinion of building services maintenance and maintenance programme and polices.

It was identified that the experts in maintenance field have very much similar ideas regarding maintenance activities and their loopholes. Four interviewees highlighted three common opinions on the general opinion of building services maintenance as i) well managed maintenance activities of building services generate profits, ii) high priority should be given to maintenance activities and iii) maintenance occur highest cost in the operating budget. Further, interviewees roughly mentioned that more than 50% of the maintenance budget is allocated for maintenance activities of building services.

The interviewees also pointed out several policies and programmes which are commonly used in each organisation as well. Most organisations are practicing preventive and predictive maintenance programmes rather than reactive maintenance in order to reduce difficulties of maintenance activities. Further, one of the Experts said that “*Since we never want the equipment to breakdown, we are practicing Zero downtime Type maintenance policy*”. According to the expert’s views, most of organisations uses zero down time based maintenance since they have identified the importance of uninterrupted building services. In addition, it is noticed that most of the organisation is following various standards such as British Standards when designing maintenance policies. Therefore, it is revealed that practitioners are more concerned in conducting effective maintenance management activities in their buildings.

4.1.2. EFFECTIVENESS OF MAINTENANCE ACTIVITIES

Secondly, personal views regarding the effectiveness of maintenance activities of building services were identified. This was discussed based on four topics as shown in Figure 2. The experts were questioned on their personal opinion of the effectiveness of maintenance activities. It was noticed that, reducing minor defects into huge deficits or financial losses, the concept of “Do it right at the first time” and efficiency of the work as their common opinion towards the effectiveness of maintenance activities.

During the discussions, it was identified that most of the building maintenance practitioners are implementing various approaches to ensure the effectiveness of maintenance activities and obtaining a number of benefits. Waste reduction, time savings, service quality, reduction of pending work, reduction of complaints, quality of materials, less breakdowns, increasing equipment lifetime, enhancement of communication procedures and customer satisfaction were identified as benefits throughout the expert survey.

Expert survey was used to identify the additional factors which affect the effectiveness of maintenance activities and validate the literature findings according to the expert’s opinions. Experts agreed with the findings of a literature survey and further added following factors.

- Addressing grievances
- Alternative options for equipment
- Approval process
- Building Management Systems
- Cost consciousness
- Data Logging systems
- Usage of personal protective equipment and safety procedures
- Employee motivation
- Financing for maintenance activities
- High interaction with managers and other maintenance staff
- Life cycle costing
- Personnel replacement
- Promoting teamwork
- Quality of material
- Statistical analysis of maintenance status
- Tool box talk
- Pre planning the way of doing maintenance activities

These factors were categorised into human related factors, technical factors, managerial factors and other factors with the comments of interviewees. The human related factors were directed at individuals or team of maintenance operational staff. The Technical factors were related to the equipment and machine issues and managerial factors were related to the management process. Any other factors which does not fall into the above three categories were considered with other factors.

4.2 STRUCTURED QUESTIONNAIRE SURVEY FINDINGS

The main objective of this research is to identify the factors, mostly affect to effectiveness of maintenance activities of building services. Hence, the structured questionnaire survey was conducted and factors were ranked with reference to the impact of each factor to ensure the effectiveness of maintenance activities using the Relative Importance Index (RII).

Structured questionnaires were distributed among the persons who are currently working in the maintenance field. 35 questionnaires were distributed and 30 completed questionnaires back to comment with the response rate of 85.6%.

Table 2: RII of Selected Factors

Rank	Factor	RII
Human Factors		
1	Employee motivation	88.00
2	Human Resource Management/man power	87.33
3	Promoting teamwork	84.67
4	Attitude and communication	84.00
5	Staff Trainings	82.00
6	Usage of personal protective equipment and safety procedures	80.00
7	Cost consciousness	76.00
8	High interaction with managers and other maintenance staff	74.67
9	Personnel competencies	74.00
10	Personnel replacements	73.33
11	Addressing of grievances	71.33
Technical Factors		
1	Quality of material	92.00
2	Equipment handling	81.33
3	Building Management systems	76.67
4	Tool box talk	76.00
5	Alternative options for equipment	74.67
6	Level of sophistication of the tools	72.67
7	Data Logging System	72.67
8	Computerized Maintenance Management System	69.33
9	Information Technology	64.67
Managerial Factors		
1	Pre planning the way of doing maintenance activities	86.00
2	Periodic maintenance	84.00
3	Manager's commitment	82.67
4	Frequency of inspection and monitoring	82.67
5	Prioritization	82.00
6	Work orders planning and control	80.67
7	Outage Control	76.00
8	Maintenance Organisation's Structure	74.00
9	Service Delivery Options	70.67
10	Maintenance Audit	70.00
Other		
1	Financing for maintenance activities	85.33
3	Spare part Inventory	83.33
2	Proper documentations	82.67
4	Approval process	80.00
5	Statistical analysis of maintenance status	76.67
6	Equipment history file	72.67
7	Life Cycle Costing	69.33
8	Legal regulations	67.33

4.3. LIMITATIONS / PROBLEMS AFFECT TO EFFECTIVENESS OF MAINTENANCE ACTIVITIES

There are limitations in building services maintenance field as mentioned previously in the literature review. However, identification of those limitations will be very much important in order to eliminate them through the factors which positively affect the effectiveness of maintenance activities. By conducting semi-structured interviews with the selected 12 persons who are currently working in maintenance field the most common limitations available in the maintenance field have been identified. The identified limitations are given in Table 3 with the factor categories. With the aid of semi structured interviews, currently available limitations in the building maintenance industry were identified. 25 limitations which faced by the maintenance teams were identified. The practitioners who are currently working on commercial buildings as maintenance engineers and managers and other maintenance professions such as assistant maintenance engineers, supervisors, and chief technical officers with 5 years or more experiences, were selected for the interviews.

Table 3: Available Limitations in the Maintenance Field

Limitation / Problem	Applicable Factor Category				Interviewees											
	Human	Technical	Managerial	Other	I 1	I 2	I 3	I 4	I 5	I 6	I 7	I 8	I 9	I 10	I 11	I 12
Less manpower backup																
Having huge purchasing procedure																
High time spending for purchasing process																
Difficulty of convince needs for contractors																
Lack of specialist /qualified technicians																
Not having enough time for activities																
Difficult to give promotions																
Leaving organisation by technicians																
Limited budget allocation																
Difficulty of getting approval																
Legal problems/Government rules																
Negligence in periodic maintenance																
Poor store management process																
Lack of trainings for maintenance activities																
Communication problems																
Dislike to use PPE																
Less quality material																
Less salaries for maintenance staff																
Customer disturbances																
Weather conditions																
Not having some spare parts in Sri Lanka/Scarcity of spare parts																
People require high cost for work at abnormal hours																
Not having enough trust between maintenance team																
Unawareness/less knowledge regarding maintenance work																
Not having special way to prove material quality																

5. FRAMEWORK DEVELOPMENT

The framework has been developed in order to provide a broad idea regarding effectiveness of maintenance activities of building services. It is important to notice that, this framework only provides the most important factors and limitations which can be easily identified in the maintenance field in commercial buildings. Firstly, framework highlights the factors which affect to effectiveness of maintenance activities of building services in commercial buildings under four topics as human, technical, managerial and other. These factors are categorised based on the level of impact to the effectiveness of maintenance using the RII score. Afterwards, the limitations of each factor are presented. Maintenance practitioners can be adhered to, this framework in order to ensure the effectiveness of maintenance activities successfully.

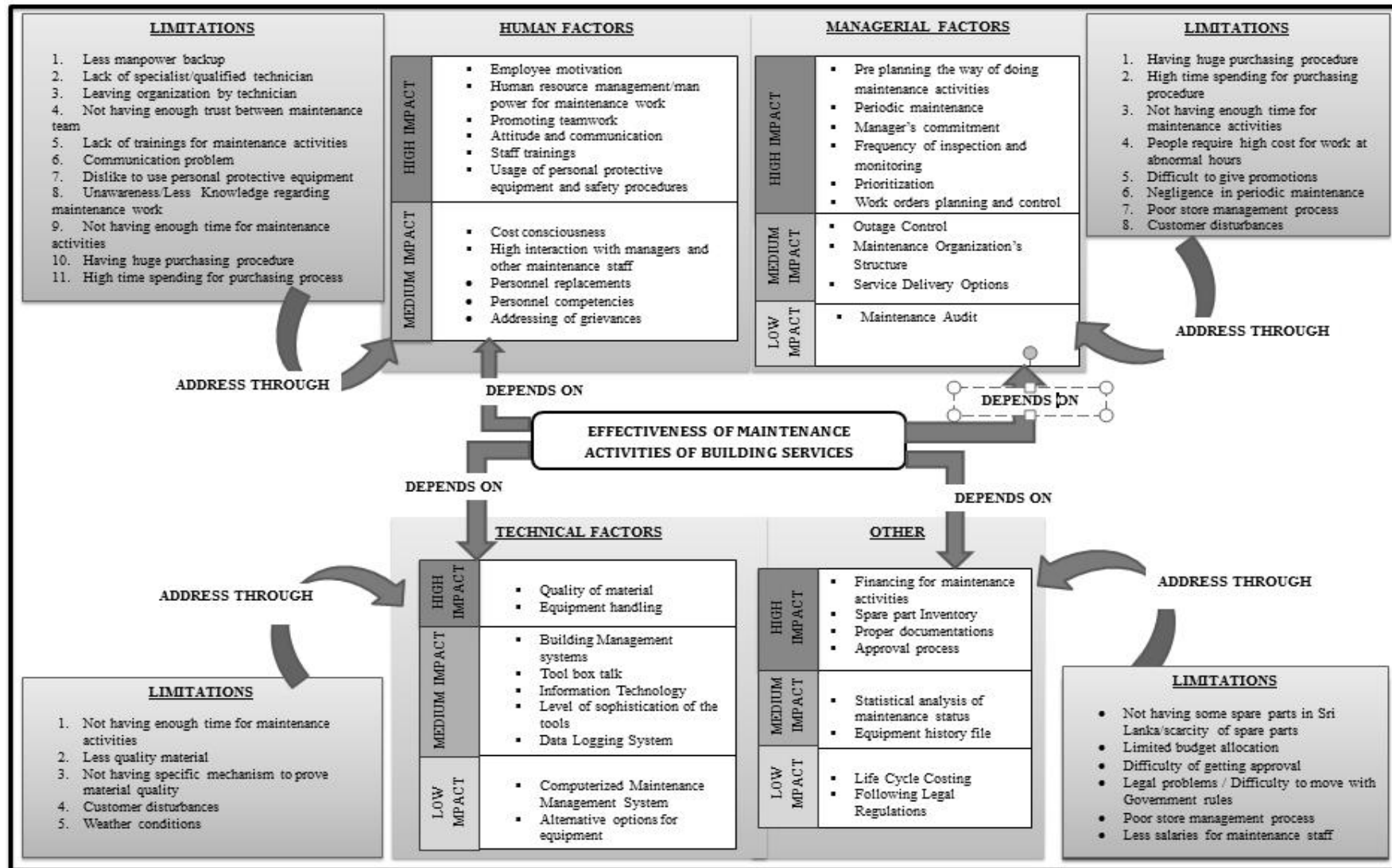


Figure 2: Framework for Ensuring Effectiveness of the Maintenance Activities in Building Service

6. CONCLUSIONS

Effective maintenance activities ensure uninterrupted building services systems. In practice, a considerable amount of organisations have given a significant attention to maintenance activities of building services. This research focused on identifying the factors that underpin effective maintenance activities in building maintenance in commercial buildings. The study mainly focused on internal factors of organisation rather than external factors and identified under human, managerial, technical and other categories. The research has been identified 38 factors which affect to effectiveness of maintenance activities and 25 limitations when performing maintenance activities. These factors were further categorized as high, medium and low. Quality of materials, Employee motivation, manpower for maintenance activities, pre planning the way of doing maintenance activities and financing for maintenance activities identified as the most critical high impact factors. Limited budget, not having enough time for maintenance activities, lack of qualified technicians and scarcity of spare parts highlighted as frequent limitations. The limitations available in maintenance activities of building services can be addressed by awakening the factors which affect to effectiveness of maintenance activities.

7. REFERENCES

- Abreu, J., Martins, P.V., Fernandes, S. and Zacarias, M., 2013. *Business Processes Improvement of Maintenance Management: A Case Study*, 9, 320-330.
- Ahuja, I.P.S. and Khamba, J.S., 2008. Total Productive Maintenance: Literature Review and Directions. *International Journal of Quality and Reliability Management*, 25(7), 709-756.
- Al-Ghanim, A., 2003. A Statistical Approach Linking Energy Management to Maintenance and Production Factors. *Journal of Quality in Maintenance Engineering*, 9(1), 25-37.
- Ali, M., and Mohamad, W. M.N.B.W., 2009. Audit Assessment of the Facilities Maintenance Management in a Public Hospital in Malaysia. *Journal of Facilities Management*, 7(2), 142-158.
- Allen, D., 1993. What is Building Maintenance?. *Facilities*, 11(3), 7-12.
- Aoudia, M., Belmokhtar, O. and Zwingelstein, G., 2008. Economic Impact of Maintenance Management Ineffectiveness of an Oil and Gas Company. *Journal of Quality in Maintenance Engineering*, 14(3), 237-261.
- Au-Yong, C.P., Ali, A.S. and Ahmad, F., 2014. Improving Occupants' Satisfaction with Effective Maintenance Management of HVAC System in Office Buildings. *Automation in Construction*, 43, 31-37.
- Bamber, C.J., Sharp, J. M. and Castka, P., 2004. Third Party Assessment: The Role of the Maintenance Function in an Integrated Management System. *Journal of Quality in Maintenance Engineering*, 10(1), 26-36.
- Ben-Daya, M. and Duffuaa, S.O., 1995. Maintenance and Quality: The Missing Link. *Journal of Quality in Maintenance Engineering*, 1(1), 20-26.
- Garg, A. and Deshmukh, S.G., 2010. Engineering Support Issues for Flexibility in Maintenance. *Asia Pacific Journal of Marketing and Logistics*, 22(2), 247-270.
- Horner, R.M.W., El-Haram, M.A. and Munns, A. K., 1997. Building Maintenance Strategy: A New Management Approach. *Journal of Quality in Maintenance Engineering*, 3(4), 273-280.
- John, G.A., Clements-Croome, D.J., Fairey, V. and Loy, H.M., 2005. Contextual Prerequisites for the Application of ILS Principles to the Building Services Industry. *Engineering, Construction and Architectural Management*, 12(4), 307-328.
- Jonsson, P., 1997. The Status of Maintenance Management in Swedish Manufacturing Firms. *Journal of Quality in Maintenance Engineering*, 3(4), 233-258.
- Lewis, A., Elmualim, A. and Riley, D., 2011. Linking Energy and Maintenance Management for Sustainability through Three American Case Studies. *Facilities*, 29(5/6), 243-254.
- Lind, H. and Muyingo, H., 2012. Building Maintenance Strategies: Planning under Uncertainty. *Property Management*, 30(1), 14-28.
- Marquez, A.C., Leon, P.M., Fernandez, J.F.G., Marquez, C.P. and Campos, M.L., 2009. The Maintenance Management Framework. *Journal of Quality in Maintenance Engineering*, 15(2), 167-178.

- Mostafa, I.S., 2004. Implementation of Proactive Maintenance in the Egyptian Glass Company. *Journal of Quality in Maintenance Engineering*, 10(2), 107-122.
- Obiajunwa, C.C., 2013. Skills for the Management of Turnaround Maintenance Projects [online]. *Journal of Quality in Maintenance Engineering*, 19(1), 61-73. Available from: <http://www.emeraldinsight.com/doi/abs/10.1108/13552511311304483> [Accessed 10 May 2014].
- Panchdhari, A., 2003. *Maintenance of Buildings*. New Delhi: New Age International Private Limited.
- Pintelon, L., Preez, N.D. and Puyvelde, F.V., 1999. Information Technology: Opportunities for Maintenance Management. *Journal of Quality in Maintenance Engineering*, 5(1), 9-24.
- Pun, K.F., Chin, K.S., Chow, M.F. and Lau, H.C.W., 2002. An Effectiveness-Centered Approach to Maintenance Management. *Journal of Quality in Maintenance Engineering*, 8(4), 346-368.
- Reis, A.C.B., Costa, A.P.C.S. and Almeida, A.T., 2009. Planning and Competitiveness in Maintenance Management: An Exploratory Study in Manufacturing Companies. *Journal of Quality in Maintenance Engineering*, 15(3), 259-270.
- Sherwin, D., 2000. A Review of Overall Models Formaintenance Management. *Journal of Quality in Maintenance Engineering*, 6(3), 138-164.
- Tam, A.S.B. and Price, J.W.H., 2008. A Maintenance Prioritisation Approach to Maximise Return on Investment Subject to Time and Budget Constraints. *Journal of Quality in Maintenance Engineering*, 14(3), 272-289.
- Tsang, A.H.C., 2002. Strategic Dimensions of Maintenance Management. *Journal of Quality in Maintenance Engineering*, 8(1), 7-39.
- Wang, C.H. and Hwang, S. L., 2004. A Stochastic Maintenance Management Model with Recovery Factor. *Journal of Quality in Maintenance Engineering*, 10(2), 154-164.
- Wang, W., 2012. An Overview of there Recent Advances in Delay-Time-Based Maintenance Modelling. *Reliability Engineering and System Safety*, 106, 165-178.
- Wu, S., Neale, K., Williamson, M. and Hornby, M., 2010. Reserch Oppertunities in Maintenance of Office Building Services System. *Journal of Quality in Maintenance Engineering*, 16(1), 23-33.
- Yam, R.C.M., Tse, P., Ling, L. and Fung, F., 2000. Enhancement of Maintenance Management through Benchmarking. *Journal of Quality in Maintenance Engineering*, 6(4), 224-240.
- Yik , F. W. and Lai, J. H. K., 2005. The Trend of Outsourcing for Building Services Operation and Maintenance in Hong Kong. *Facilities* [online], 23(1/2), 63-72. Available from: <http://www.emeraldinsight.com/doi/abs/10.1108/02632770510575901> [Accessed 10 May 2014].
- Zhu, G., Gelders, L. and Pintelon, L., 2002. Object/Objective-Oriented Maintenance Management. *Journal of Quality in Maintenance Engineering*, 8(4), 306-318.