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## **A framework for physical asset risk management in the Sri Lankan clothing industry**

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Thatshayini Premanathan, Damitha Rajini and  
Tharindu Lakruwan Wickremanayake Karunaratne\*

Department of Building Economics,  
Faculty of Architecture,  
University of Moratuwa,  
Moratuwa, Sri Lanka  
Email: pthatsha@gmail.com  
Email: damee\_uom@yahoo.com  
Email: tkarunaratne.uom@gmail.com  
\*Corresponding author

**Abstract:** Increasing demand for operational efficiency in clothing manufacturing organisations necessitates the management of risks associated with their physical assets. The aim is to develop a framework for effective physical asset risk management (PARM) in the Sri Lankan clothing industry. This was approached through a multiple case study research method carrying out five case studies. The required data were collected through semi-structured interviews and the data analysis was carried out using content analysis. The research findings revealed that PARM in the Sri Lankan clothing industry has not received adequate attention. Adopting standardised risk management (RM) procedures, convincing top management about the importance of PARM and achieving top management support and making stakeholders aware about PARM are the keys to achieve effective PARM in the Sri Lankan clothing industry. The PARM framework will be a useful guide for practitioners in the clothing industry to manage physical asset related risks effectively.

**Keywords:** physical asset risk management; PARM; clothing industry; Sri Lanka.

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**Biographical notes:** Thatshayini Premanathan has earned her BSc (Hons) in Facilities Management from the University of Moratuwa, Sri Lanka. She has published journal and conference papers. Her research interests include physical asset management, risk management, occupational health and safety, quality management and corporate social responsibility.

Damitha Rajini is a Lecturer attached to the Department of Building Economics, University of Moratuwa, Sri Lanka and she is currently reading for her PhD at the University of Colombo, Sri Lanka. Her research interests include operations management, outsourcing, physical asset management and supply chain management.

Tharindu Lakruwan Wickremanayake Karunaratne is currently reading for his PhD. He has earned his BSc (Hons.) in Facilities Management (with first class) and MSc. He has research degrees from University of Moratuwa, Sri Lanka. He has also worked as a Research Scholar at University of Moratuwa for two years. His research interests are in energy management, carbon pricing, sustainable development and physical asset management.

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## 1 Introduction

Physical asset management (PAM) is progressively becoming a more vital area for reaching positive decisions for improved organisational performance. It is considered as an essential management to an organisation to fulfil its strategic goals (Mitchel, 2002). PAM helps to maximise the performance of assets and minimise cost and risk which can be associated with them (Emmanouilidis and Komonen, 2013). Within ISO 55000 standards, RM is seen as an indispensable aspect of PAM and the alignment of PAM with RM approach is an essential part of it (Deloitte Enterprise Risk Service, 2015). The physical asset risk management (PARM) approach gives a cost effective way to minimise expenditure in the management of assets, preserving reliability objectives and running within safety and environmental rules and regulations (Bharadwaj et al., 2011). However, as the empirical findings suggest, the current PARM practices in the industry are not at an adequate level. Therefore, the aim of this paper is to investigate the PARM practices in the industry, identify the issues in the current practice, propose strategies to overcome the identified issues and finally to develop a framework for effective PARM. However, this research is limited to collect data from Sri Lankan clothing manufacturing organisations.

The paper starts with a review of literature related to the key concepts of the study. Then the method used in achieving the aim, findings of the study and the developed framework for PARM in clothing industry in Sri Lanka are presented respectively.

## 2 Literature review

### 2.1 *Risks associated with physical assets*

Physical assets are major resources for business activities which continuously play a highly essential key role in optimising business profitability (Schuman and Brent, 2005). In the present business environment, PAM has become a key challenge for business firms and has obtained a more important role as a management function (Emmanouilidis and Komonen, 2013). To gain a greater value, the PAM process should extend from design, procurement and installation through operation, maintenance and retirement over the complete asset life cycle (Blanchard, 2014). According to the British Standards Institution (2008), PAM is a set of disciplines, methods, procedures and tools, used to optimise the whole life business impact on costs, performance and risk exposures associated with the availability, efficiency, quality, longevity and regulatory/safety/environmental compliance of the company's physical assets. Therefore, an important aspect of PAM is to strike the right balance between performance, cost and risk in pursuing the enterprise goals (The Institute of Asset Management, 2015;

Emmanouilidis and Komonen, 2013). Hence, managing risks associated with assets and keeping risks with acceptable tolerance is one of the essential objectives of PAM (Macintosh et al., 1998).

Risk can be defined as the likelihood of an event that will harm others by a hazard (Eiser et al., 2012). Physical assets are exposed to different risks with a wide variety in probability, time span (immediate or future impact) and impacted business values such as safety, reliability, sustainability, etc. (Korn and Veldman, 2008). In addition to the risks that are connected with the industrial working environments, there are several other physical assets related risks (Lind et al., 2008). Deloitte Enterprise Risk Service (2015) has identified the risks which are related to physical assets as, gradual deterioration, mechanical breakdown, operational safety, regulatory/legal compliance, third party damages, natural disasters, business continuity, environmental damage, construction damage, operational errors, design and production errors or defects, theft or burglary, cyber-attack and terrorism and sabotage. However, ISO 55000 has categorised all possible physical assets related risks into six specific categories as physical failure risks, operational risks, risks associated with natural environmental events, risks associated with the factors outside the organisation's control, stakeholder's risks and risks associated with different life cycle phases of assets (Hollingdale, 2014). As stated by ISO 55000 (2014), an organisation should take necessary actions to address risks when planning its PAM. An effective PARM is therefore important, so each business can manage risk, know when to take the time over a decision and also to pinpoint when and why a risky decision was taken, when looking back. Hence, PARM is a complex part of organisational activities and must be treated as such, in order to achieve the right balance between assessing risk and taking it (Pearson, 2016). This implies that an organisation should establish, implement and maintain documented processes for the ongoing identification and assessment of physical asset related risks, and the identification and implementation of the necessary control measures throughout the life cycle of the assets (Cohen, 2010).

## *2.2 PARM process*

RM plays a key role in PAM and industries tend to develop various processes and approaches, which may enable to efficiently address these issues and manage associated risks (Komljenovic et al., 2016). As per Pearson (2016), an effective PARM process does not necessarily remove all risks from an organisation's operations unless that is what the organisation needs to do. It is a process that systematically understands each of organisation's physical assets and helps the organisation to make the right decision for business operation with all the potential risks laid bare. The literature does not provide any standardised RM process especially for PARM. As Mobley (2016) mentioned, PARM is a big operation in these days and it is up to each individual organisation to put the correct processes in place to suit their product, service and style.

RM process should generally consist of the risk identification, evaluation of the preventive measures and their functionality, estimation of the exposure to the hazards and the evaluation of the tolerability of the risk (British Standards Institution, 2004). However, ISO 31000:2009 provided a generic guideline which can be applied to any type of risk, whatever its nature, whether having positive or negative consequences. It can be used by any public, private or community enterprise, association, group or an individual.

Therefore, ISO 31000:2009 is not specific to any industry or sector and it is similarly applied for PARM as well. The RM process introduced by ISO 31000:2009 involves risk identification, analysis, evaluation and treatment and the whole process needs to be supported with required communication, consultation, monitoring and review (ISO 31000, 2009).

The risk identification phase as the first stage in the RM plays a leading role for effective RM (Tchankova, 2002). The purpose of a risk assessment is to systematically identify all of the risks associated with a task, activity or process, and put appropriate controls in place to eliminate or reduce the risks associated with that activity. After the risk assessment, the organisation has to ascertain what sort of actions is needed and their priority. Obviously something with a higher risk rating is of greater priority. Once decided on the controls which the organisation is going to put in place, the risk assessment is authorised and the organisation has to implement these controls. This may require the addition of further training, procedures, guidelines, etc. to facilitate implementation of some controls. However, there is no use of implementing controls, if the organisation does not monitor and review what they have implemented. Therefore, continuous monitoring is essential for PARM to be effective (Aven, 2016).

### *2.3 Tools and techniques used for PARM*

Various risk identification, analysis and evaluation tools can be applied at different stages of PAM which can be either qualitative or quantitative. According Lind et al. (2008); Papadakis and Chalkidou (2008) and Aneziris et al. (2010), there are lack of systematic risk assessment techniques which are used specifically for PAM. Though several RM tools have been designed for industrial sectors, those tools typically focus on general working environment risks or are designed for a certain process or specific equipment (National Research Council (US) Committee, 2003). However, use of validated, systematic RM tools together with standardised guidelines for determining the severity of the risk and the likelihood of the occurrence can help to diminish subjectivity in risk assessments (British Standards Institution, 2004). As a risk analysis tool, BS 8800 (2004) has developed a risk rating matrix where the likelihood of harm is expressed much broadly as almost certain, likely, possible, unlikely and rare. Risk rating matrix is common method used for risk ranking utilises powered tools used in RM and help guide in the process of decision making in organisations (Elmontsri, 2014). Table 1 displays a list of tools and techniques which are used for risk identification, risk analysis and risk evaluation as introduced by ISO 31010 (2009).

### *2.4 PARM in clothing manufacturing organisations*

Asset-intensive organisations such as manufacturing rely for their operations on assets that are expensive, extensive and/or complex, and have a major impact on organisational performance over extended periods (Mardiasmo et al., 2008). In clothing industry, there are massive quantity of physical assets along with machineries used for manufacturing, transportation, storing and for other activities. Therefore, large-scale clothing manufacturing firms are subjected to physical asset related risk factors present in different magnitudes and different levels. Therefore, management of such risks should be given a special attention. Though PARM is an area that has been received increasing attention, researches which address PARM and PARM in clothing manufacturing sector

is limited. Further, researches which have addressed PAM practices in Sri Lanka are also an area which has not received an adequate attention (Thatshayini and Rajini, 2017).

**Table 1** Tools and techniques used for RM

<i>Risk identification</i>	<i>Risk analysis</i>	<i>Risk evaluation</i>
Brainstorming	HAZOP	HAZOP
Semi structured interview	Hazard analysis and critical	Hazard analysis and critical
Delphi	Control points	Control points
Checklist	Scenario analysis	Scenario analysis
Primary hazard analysis	Business impact analysis	Business impact analysis
HAZOP	Root cause analysis	Root cause analysis
Control points	Failure mode effective analysis	Failure mode effective analysis
Scenario analysis	Fault tree analysis	Fault tree analysis
Business impact analysis	Event tree analysis	Cause and consequence analysis
Root cause analysis	Cause and consequence analysis	Decision tree
Failure mode effect analysis	Cause and effect analysis	Human reliability analysis
Fault tree analysis	Layer protection analysis	Bow tie analysis
Event tree analysis	Decision tree	Reliability centred maintenance
Cause and consequence analysis	Human reliability analysis	Monte Carlo simulation
Cause and effect diagram	Bow tie analysis	Bayesian statistics
Layer protection analysis	Reliability centred maintenance	FN curves
Decision tree	Markov analysis	Risk indices
Human reliability analysis	Bayesian statistics	Consequence/probability matrix
Bow tie analysis	FN curves	Cost/benefit analysis
Reliability centered maintenance	Risk indices	Multi-criteria decision analysis
Snack circuit analysis	Consequence/probability matrix	
Markov analysis		
FN curves	Cost/benefit analysis	
Risk indices	Multi-criteria decision analysis	
Consequence/probability matrix		
Cost/benefit analysis		
Multi-criteria decision analysis		

*Source:* Adapted from ISO 31010 (2009)

### 3 Research design

As per Yin (2013), research design is an action plan from the initial stage of the research to the final conclusions. The aim of this research was to develop a framework for PARM

in clothing industry in Sri Lanka which was achieved from the opinions of the physical asset related professionals in the clothing industry. Accordingly interpretivism was preferred over positivism for this research. After defining the research philosophy, a suitable research approach should be selected to deal with the research problem (Hapuarachchi, 2007). Kothari (2004) explained that, qualitative research approach is a subjective, exploratory, attitudinal and assessing opinions and behaviours. As this research required assessing subjective data such as opinions and behaviour, it holds a qualitative position. According to Yin (2009), research questions which involve 'why' and 'how' questions can only be investigated through case studies. As this research involves questions start with 'why' and 'how', case study method was selected as the most appropriate method for this study. Accordingly, five clothing manufacturing organisations were selected as case studies in this research. As Sekaran (2003) stated, when interviews are conducted in semi-structured manner, it enables to adapt the questions necessary, clarifies doubts and ensures that the respondent is properly understood by repeating the questions. Thus, the data collection in this research was done from one respondent from each case, mainly through semi structured interviews. Altogether five interviews were conducted and the collected data were analysed adopting content analysis. The details of the selected cases and respondents have been summarised in Table 2.

**Table 2** Profile of the cases

<i>Organisations</i>	<i>Nature of business</i>	<i>Respondents</i>	<i>Profile of respondents</i>	<i>Experience in the field of PAM</i>
Case A	Clothing	R-A	Facilities engineer	More than 10 years
Case B	Clothing	R-B	Compliance and sustainability executive	More than 8 years
Case C	Clothing	R-C	Maintenance manager	More than 10 years
Case D	Clothing	R-D	Facilities engineer	More than 20 years
Case E	Clothing	R-E	Maintenance manager	More than 10 years

## 4 Research findings and discussion

The following sections discuss the findings of the research, answering the following three research questions of this study.

- How physical asset related risks are currently managed?
- What are the barriers for PARM in Sri Lankan clothing industry
- What are the strategies to overcome the barriers for PARM in Sri Lankan clothing industry?

### 4.1 Current PARM practices in Sri Lankan clothing industry

This section presents the current PARM practices of clothing manufacturing organisation in Sri Lanka, answering the first question of the study, 'how physical asset related risks are currently managed?'.

The physical assets used in clothing manufacturing organisations can be divided into two groups as physical assets used to carry out core business activities and physical assets used to carry out business support activities. The first category generally includes sewing machines, cutting machines, washing machines, etc. whereas the second category of assets, which are also called as utility assets include generators, boilers, air compressors, transformers, etc. All the selected cases are leading clothing manufacturing companies of the country. Engineering departments of cases A, B and D are responsible for managing their physical assets whereas maintenance department and maintenance management committee are responsible for managing physical assets of cases C and E respectively. The heads of these departments or committees have the ultimate responsibility for managing the physical assets and all these personnel possess adequate technical knowledge to manage physical assets and enough experience in the field of PAM to carry out their works.

As the research findings showed, none of the organisations follows a standardised PARM procedure. In all the cases, there is no any specific procedure for PARM, but, the general procedure which is applicable for RM in the entire organisation is practiced. Further, PARM processes practiced by all the cases are almost similar to the RM procedures which has been introduced by ISO 31000:2009 which includes risk identification, risk analysis, risk evaluation and risk treatment. Risk identification is the first step of RM. The case studies showed that all the cases have given the priority to risk identification process. After identifying the risks and root causes, the risk level is measured based on the severity and impact. The risk level is measured to identify the criticality and non-criticality of risks and finally to take corrective actions. This measurement is based on the severity and the frequency of the risks. Once the risk level was measured, risk response actions are taken. In all the cases, the common treatment methods such as elimination, substitution, engineering control, administrative control, and transfer to insurance are used. To treat higher level risks, the selected organisations generally go for elimination or substitution. If there is any risk which cannot be handled by themselves, they prefer to transfer the risks to insurance.

The respondents were also interviewed to gather data about the tools and techniques currently used by them for PARM. The research findings showed that the root cause analysis and check list analysis are practiced by all the selected cases to identify physical asset related risks. Root cause analysis is used to identify prime causes of an incident instead of dealing with the recent causes. According to R-E, potential failures and risks can be easily predicted using checklists. In addition, past documents reviews and brainstorming methods are largely used to identify risks in selected cases. R-A stated that by referring the history of a system's activity, it is easy to identify the past issues and rectification activities, as well as to observe the potential risks involved. Therefore, past documentation review allows risks to be identified in a structured manner. Brainstorming sessions used for high-level discussions, for more detailed review of a particular problem where problems need to be identified. They are conducted within regular intervals i.e. once every three months and once a month in cases A and D respectively. The most widely used risk analysis method is the risk rating matrix. In case A, it is used for identifying the frequency, the impacts of risk event and the level of risk. The risk levels are calculated in cases A and C, on the basis of probability and impact, using a calculator. According to the R-C, the risk calculator illustrates the probability in percentage of time, impact and risk level. Once the inputs for probability and consequences are given, the

risk level is shown automatically whether it is high risk, medium or low risk. Therefore, the risk calculator can be considered as a semi quantitative risk analysis tool. However as per the findings, it is clear that though numerous tools and techniques are available for PARM (refer Table 1), use of tools and techniques for PARM is at a lower level in Sri Lankan clothing industry.

#### *4.2 Barriers for PARM in Sri Lankan clothing industry*

Barriers are the factors that constrain effective PARM. Hence, answering the research question ‘why PARM is not adequately practiced?’ following section presents the barriers for effective PARM in Sri Lankan clothing industry.

Not having a specific standardised format to assess risk level was considered as the main barrier for effective PARM by all the interviewees. Because of this, organisations do not know the actual procedure of the RM and how to estimate the severity and probability of risks.

As the R-B stated, the RM is not an easy procedure as it takes a longer time period to identify, understand, observe, analyse and evaluate the risks. And it is not just an activity, it should be an ongoing process and updated on regular basis. Though a considerable amount of employees and resources are therefore required to carry out PARM within an organisation, as the majority of the respondents highlighted, it is lacking at the present.

Top management commitment is an essential element for commencing or practicing any type of activity in an organisation. According to R-B, the top management always focuses on core functional areas and always the priority is given for core functions rather than supporting functions. Due to this, an adequate motivation is not received for PARM. Further, the lack of knowledge of top management on the importance of PARM could also be noticed through the study as they have added physical asset related risks in the general RM plan.

To identify the failures and issues in systems and equipment in the early stage, use of predictive maintenance equipment such as vibration analysers and temperature analysers are required. However, as per the research, limited usage of advanced predictive maintenance tools to identify the condition and fault mode of systems could be identified as another obstacle for effective PARM.

Moreover, there is no solid past data and the decisions are made based on opinions and the judgements of experts. Hence, subjective probabilities are drawn from the degree of belief or confidence of the decision maker on the basis of evidence available. Making decisions totally based on the experts’ judgements and not using advanced tools and techniques, limit the accuracy of such decisions and they will negatively affect the effectiveness of PARM.

The effectiveness of PARM largely depends on the assessment of level of impact and the likelihood of the risks. However, as the R-A stated, it is very difficult to accurately say at what percentage level the workers will be impacted and at what time they will be impacted due to physical, chemical and ergonomically hazards. Therefore, to address the issues, appropriate tools and techniques are necessary, yet lacking in the Sri Lankan context.

PAM activities are carried out by the employees of the organisation and therefore it is essential that they are well knowledgeable of all the areas related to PAM. Though most of the employees are aware of maintenance and technical procedures, lack of knowledge and awareness of them on PARM is evident.

When an organisation procure a new system, asset register should be updated, based on which the risk register will be updated. As R-B disclosed, RM is an ongoing process and the process needs to be checked, reviewed and recorded throughout the lifecycle of assets. Though the selected cases have established such procedures to be followed, as the respondents highlighted, the required details are not properly recorded by the employees in timely manner, being a barrier for PARM.

As R-C stated, there are many parties involved with PAM including managers, system operators, maintenance technicians, suppliers or manufacturers, service providers and insurance parties. Therefore, PARM cannot be effectively done unless the stakeholders understand the procedures well enough. However, it could be identified that there is lack of awareness of stakeholders on PARM, which confines the organisation from achieving effective PARM. The barriers of the PARM in the five cases were analysed are shown in Table 3 and those will be basis of the above discussion.

**Table 3** Barriers of PARM in Sri Lankan clothing industry

<i>Barriers in PARM</i>	<i>Case A</i>	<i>Case B</i>	<i>Case C</i>	<i>Case D</i>	<i>Case E</i>
No specific standardise format to asses risk	✓	✓	✓	✓	✓
Require considerable amount of resources (time, money, employees)	✓	✓		✓	✓
Lack of top management commitment	✓	✓			✓
Lack of advance predictive maintenance tools	✓			✓	✓
Totally based on assumptions				✓	✓
Lack of awareness of stakeholders	✓		✓		
Frequency and impact level of risks cannot be exactly assessed	✓				
Has to be updated regularly		✓			
Lack of knowledge and awareness of workers			✓		

### *4.3 Strategies to overcome the barriers for PARM in Sri Lankan clothing industry*

The third research question, ‘how physical assets related risks can be effectively managed?’ is addressed in this section by discussing the strategies that need to be taken in order to overcome the identified barriers for PARM in Sri Lankan clothing industry.

The case study findings suggested that, in order to recover from the barriers associated with PARM, the organisation should first ensure that all the workers and related stakeholders of PAM are aware of PARM procedure of the respective organisation. The R-C proposed that continuous knowledge sharing by means such as workshops organised for management and workers will improve their knowledge on PARM and working attitude thus, enabling the organisations to achieve effective PARM.

All the interviewees recommended that, it is better to adopt to a standard procedure to control risks which will help to mitigate the barriers in PARM procedures. As stated by R-B, adopting standard procedures such as ISO 55,001 asset management system standard will enable them to understand what should be done and what should not. Based on these guidelines, they can easily keep the order within the industry.

According to R-E, maintaining RM plan and risk register is crucial for future reference and as a guidance tool. Using these strategies, the barrier of not maintaining proper records, can be minimised. It could also be identified that hiring expert consultants for PARM is an appropriate approach to overcome the barriers. For an example, R-A stated that currently they conduct brainstorming discussions only with engineering department or the respective technical department and it will better to obtain the opinions of experts of PAM which will enable them to identify advanced and updated PARM practices.

Providing employees with safe workplaces, safe work stations and safe working procedure are main responsibilities of all the organisations, especially manufacturing organisations where huge amount of machinery are involved. Therefore, another strategy revealed by the respondents is to incorporate PARM findings with health and safety procedures so that the required control mechanisms can be easily identified.

As mentioned by the R-D, current maintenance strategy followed by the clothing industry is preventive maintenance. However, it is beneficial to follow advanced predictive maintenance to easily identify the condition of whole system and components inside of it though it is a costly solution.

The managers who are responsible for PARM can convince the top management, the importance of PARM in achieving organisational ultimate objectives. Further, organisations should include PARM into their organisational strategy so that those strategies will be communicated to the middle level management and the operational level.

The findings disclosed that, training is crucial to reduce the barriers in the PARM process. For an example, the R-C recommended to provide practical experiences to workers to enhance the attitudes towards the RM. Further, safety audit programmes which review safety workstations and workers will also help to mitigate the barriers which are related to PARM. Carrying out in-house safety audits or hiring external safety audit teams for occupational health and safety assessment series (OHSAS), 5S and safety workplace investigations will also helpful to overcome the barriers and enhance the PARM procedures in Sri Lankan clothing industry.

## **5 Framework for effective PARM in Sri Lankan clothing industry**

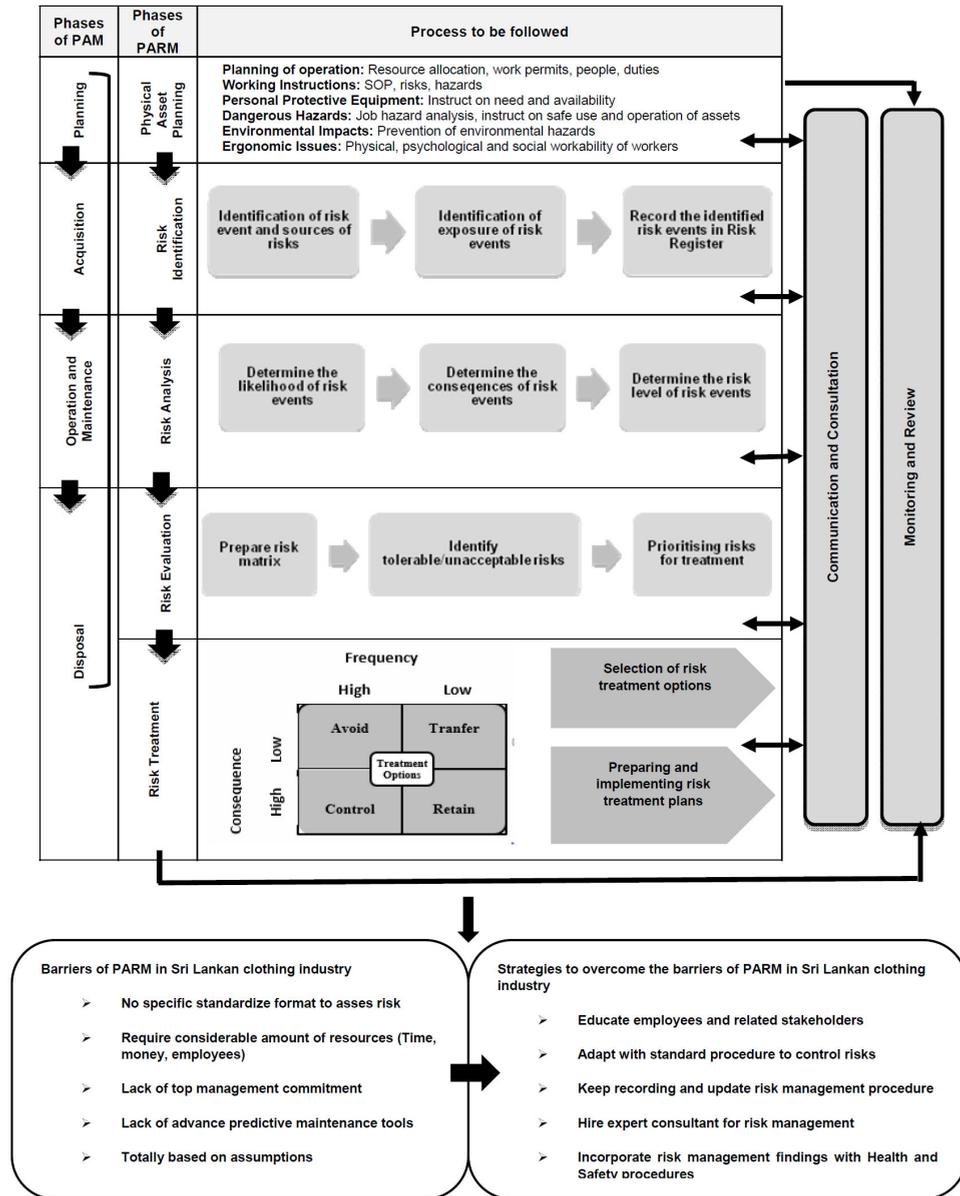
Physical assets have recognised as a vital problem area which need priority. Thus, PARM deserves utmost attention in apparel industry than other industries. Apparel industries are exposed to a number of physical asset related uncertain events. Improper operation of equipment and machineries in apparel industry could minimise operational efficiency and unable this industry to achieve competitive advantage. By identifying the current practices and the best practices, a framework for PARM was developed with the intention of providing a significant research output to Sri Lankan clothing industry.

The developed framework is presented in Figure 1.

From planning stage to disposal stage of physical assets, PARM procedures such as, physical asset planning, risk identification, analysis, evaluation and treatment should be incorporated to have proper PARM in the organisation. Physical asset planning should be undertaken when the physical assets comes into the premise. During the planning stage, planning of physical assets operation, determining work instructions, providing personal protective equipment as well as identification of dangerous hazards, environmental

impacts and ergonomic issues should be done. The details regarding physical assets should be recorded in a specific register called Physical Asset Register which will form the broadest part of PARM.

**Figure 1** Framework for effective PARM for Sri Lankan clothing industry



Once moved into risk identification stage, the risk events which are related to physical assets, sources of such risks and their exposure should be identified with the help of risk identification tools and techniques. The risk identification should be done in the planning stage, when obtaining physical assets into the building, when receiving maintenance task

or planned maintenance operation or in the disposal stage of the physical assets. The identified risks need to be recorded in a risk register.

During the risk analysis stage, the organisation has to determine the likelihood of risks, consequences and the level of risk to measure the correct level of risk exposure such as high, medium and low.

Then, risk evaluation process should be carried. In this phase, the organisation can prepare the risk rating matrix to identify the tolerable and unacceptable risks and to prioritise risks for treatment. Once the risk evaluation is done, the risk treatment options need to be chosen to respond and mitigate the risks within the organisation. The treatment option can be identified as avoid, control (engineering control and administrative control), transfer to third party and retain. At the end of this phase, risk treatment plans should be implemented.

Maintaining a record keeping system and communication of required information for the stakeholders is essential for continual improvement of PARM. Further, continual monitoring and review of the activities need to be carried out throughout the PARM process.

## **6 Conclusions**

The study found that the PARM practices in Sri Lankan clothing industry is not at a satisfactory level, though the management of risks associated with maintenance of assets have been received an adequate attention. For the research, the cases were selected only from Sri Lankan apparel industry to avoid complexities which may arise when evaluating different industries simultaneously. Further this research was limited to study about the PARM practices from apparel industries and the case study sample was limited to five apparel industry due to the time constrains. The study further identified a number of barriers which confine the clothing manufacturing organisations in achieving effective PARM practices. However, by educating employees and related stakeholders, adopting standard procedures to control risks and keep records and updating PARM procedures, convincing the top management and the employees about the importance of PARM, incorporating PARM findings with health and safety procedures, obtaining experts' opinions and using advanced predictive maintenance techniques, the clothing manufacturing industry will be able to overcome those barriers and improve their current PARM practices. Based on the research findings, framework for effective PARM in Sri Lankan clothing industry was developed and it will facilitate the Sri Lankan clothing industry to successfully adopt PARM practices so that the maximum output from their physical assets can be obtained. Further, the findings of the study will be a useful guide and provide a sound basis to the researchers who are working on the area of PARM.

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## **Appendix**

### *Interview guideline for case study*

#### *Identification of background information*

Name of the organisation:

Nature of the business:

Respondent's name (optional):

Designation:

Date: --/--/----

#### *General information section*

- 1 What are the types of critical physical assets used in your organisation?
- 2 Can you briefly explain the physical asset management procedures of the organisation?  
(E.g., responsible department, responsible people, how do you generally do the procedure?)

#### *Risk management in physical asset*

- 3 What is your opinion about risk management regarding physical assets?
- 4 What are the driving factors or main motivations for you to implement physical asset risk management practices in your organisation?
- 5 For the risk management procedure, do you follow any standard like ISO 31000: 2010 or under general practice?
  - Yes
  - No
- 6 If yes, what are the procedures/ steps to carryout risk management?

#### *Risk identification*

- 7 In which stage of physical asset lifecycle, do you do risk identification process?
- 8 What are the activities that you follow in risk identification process?
- 9 What are the issues does your organisation face in risk identification process?

#### *Risk analysis*

- 10 In which stage of physical asset lifecycle, do you do risk analysis?
- 11 What are the activities do you follow in risk analysis process?
- 12 What are the issues does your organisation face in risk analysis process?

*Risk evaluation*

- 13 In which stage of physical asset lifecycle, do you do risk evaluation?
- 14 What are the activities do you follow in risk evaluation process?
- 15 What are the issues does your organisation face in risk evaluation process?
- 16 If yes, how often do you conduct risk assessment
- 17 Monthly
- 18 Quarterly
- 19 Bi-annually
- 20 Annually

*Risk treatment*

- 21 In which stage of physical asset lifecycle, do you do risk treatment process?
- 22 What are the activities do you follow in risk treatment process?
- 23 What are the issues does your organisation face in risk treatment process?

*Methods used for physical asset management*

- 24 What kind of tools and techniques do you use for risk assessment?

<i>Tools and techniques</i>	<i>Risk assessment process</i>			<i>Risk evaluation</i>
	<i>Risk identification</i>	<i>Risk analysis</i>		
		<i>Consequences</i>	<i>Probability</i>	<i>Level of risk</i>
Brainstorming				
Semi structured interviews				
Delphi				
Checklist				
Primary hazard analysis				
Hazard and operability studies (HAZOP)				
Hazard analysis and critical control points (HACCP)				
Environmental risk assessment (ERA)				
Structure << what if? >>				
Scenario analysis				
Business impact analysis				
Root cause analysis				
Failure mode effect analysis				
Fault tree analysis				

24 What kind of tools and techniques do you use for risk assessment? (continued)

<i>Tools and techniques</i>	<i>Risk assessment process</i>			<i>Risk evaluation</i>
	<i>Risk identification</i>	<i>Risk analysis</i>		
		<i>Consequences</i>	<i>Probability</i>	<i>Level of risk</i>
Event tree analysis				
Cause and consequence analysis				
Cause-and-effect analysis				
Layer protection analysis				
Decision tree				
Human reliability analysis				
Bow tie analysis				
Reliability centred maintenance				
Sneak circuit analysis				
Markov analysis				
Monte Carlo simulation				
Bayesian statistics				
FN curves				
Risk indices				
Consequences/probability matrix				
Cost/benefit analysis				
Multi-criteria decision analysis				
SA – strong applicable		NA – not applicable		A – applicable

25 Have you achieved the expected benefits from the physical asset risk management procedures?

*Barriers in risk management in physical asset management*

26 What are the barriers (restricting factors) do you face in implementing physical asset risk management in your organisation?

27 What are the actions that you can take to overcome those barriers?