RISKS AND RISK ASSESSMENT METHODS IN INDUSTRIAL MAINTENANCE IN SRI LANKA

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ABSTRACT

Studies on industrial maintenance operations worldwide have identified several maintenance specific risks such as working at heights, the pressure of time, etc. However, there is a dearth of published research on risks and risk assessment methods in industrial maintenance in the case of Sri Lanka. This study therefore aims at identifying the risks and risk assessment methods in industrial maintenance in Sri Lanka. The main objectives of the study were to identify the occupational risks and safety issues in maintenance work and the risk assessment methods in place in the Sri Lankan context. This was undertaken through a study of three manufacturing organisations which are involved in producing fast-moving consumer products. According to the findings, the risks which affect maintenance work can be categorised as organisational risks, unsafe acts and local workplace risks. The findings indicate that the most typical risks associated with maintenance are cuts, slips and falls, with severe or fatal injuries the result of worker disregard for standard operating procedures and/or failure to use the protective equipment provided. It was also found that check lists, brainstorming, and decomposition techniques are the preferred methods in maintenance for risk identification while a risk-rating matrix is used for risk analysis. The findings of the study highlight the safety risks entailed in the maintenance operations of manufacturing organisations and the risk assessment tools used in identifying the risks. The findings of the research will be useful for those in industrial maintenance operations for the purpose of managing risks effectively by designing work environments that are risk-fee and for educating workers on the importance of paying due attention to risks and the need to follow instructions that are in place on safety procedures in the workplace.

Keywords: *Maintenance, Risk Assessment, Risk Analysis, Safety Risk, Sri Lanka.*

1. INTRODUCTION

The proper maintenance of properties and facilities in the workplace is essential for the efficient functioning of any organisation (Booty, 2006). A recent study by Lind (2009) asserts that maintenance, in the case of a company, has the direct and indirect aim of supporting production as well as management processes. The term "maintenance" can encompass all the work relating to the economic preservation of facilities, equipment and systems at a satisfactory level for the purpose of performing their designated functions (Lewis and Payant, 2007). Such preservation entails for the workers charged with maintenance a variety of work-related risks as well as working-environment-related risks (Lind *et al.*, 2008). Risk, however, can have different meanings. Alexander (2000), for instance, defines risk as a hazard, an unsafe practice, a peril capable of being insured, or a statistical probability. Risks, normally, can be defined as the probability or likelihood of someone being harmed by a hazard (Barnard, 1998). Most studies on safety risk in maintenance focus on the aspect of human performance and the risk it poses to the maintenance process (Lind, 2008). But, although there has been much focus in maintenance-related research on the system's post-maintenance condition, there has not been up to now a systematic and methodical approach to examining the impact or risk of maintenance operations on the humans who perform maintenance-related functions (Kelly and Mc Demid, 2001; Lind, 2008).

However, since work tasks and the working environment vary in industrial maintenance, companies need occupational health and safety management systems in order to enable them to prevent and mitigate accidents by identifying and prioritising the most essential hazards and to manage the hazards and to adopt

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preventive measures (Lind *et al.*, 2008; Papadopoulos *et al.*, 2010). Thus, there is a clear need for companies to place emphasis on establishing risk assessment methods that are clearly linked to the implementation of practical risk reduction measures (Kogi, 1997). Therefore, risk assessment is a structured and systematic procedure which includes the accurate identification of hazards and the appropriate estimation of the risks arising from them for the purpose of making inter-risk comparisons in order to control or avoidance them (ISO 31010, 2009). There are various risk assessment tools and methodologies available to help enterprises and organisations assess their health and safety risks (European Agency for Safety and Health at Work, 2010). According to Hughes (2008), risk assessment methods are used to decide on priorities and to set objectives to eliminate hazards and to reduce risks. As the European Agency for Safety and Health at Work (2010) states, the most common risk assessment tools are checklists, guides, guidance documents, handbooks, brochures, questionnaires and free interactive software, including downloadable applications which are usually sector-specific.

Risk assessment provides the foundation for successful health and safety management and is a key to reducing work-related accidents and occupational diseases, which in turn helps improve work place health and safety as well as business performance (Payne, 2000; European Agency for Safety and Health at Work, 2009). Therefore, the implementation of a safety risk assessment system which is designed specifically for maintenance-related activities may enhance the efficiency of the maintenance process and will in turn aid the business organisation to achieve its ultimate goals and objectives effectively and efficiently.

2. INDUSTRIAL MAINTENANCE

The term "maintenance" can be defined as all the work relating to the economic preservation of facilities, equipment, and systems at a satisfactory level in order to perform their designated functions (Lewis and Payant, 2007). In an organisation, the maintenance activities can be divided into three main elements as the technical, the human and the economic aspects to and consequences of maintenance (Thorsteinsson and Hage, 1992 cited Lind, 2009).

The maintenance operations of an organisation directly and indirectly support its production and management processes. For example, the promotion of economic efficiency by ensuring the trouble-free use of process equipment and minimising downtime contributes indirectly to economic efficiency, process reliability and product quality by enhancing overall production safety (Lind, 2009). Failure in maintenance operations can jeopardise all such benefits and become the source of accidents, which would be dangerous to human health, production and/or the environment.

Maintenance operations can be examined in various ways. Lewis and Payant (2007) has categorised maintenance operations into two main groups as corrective maintenance, which is also called breakdown maintenance, and preventive maintenance, which is also called time-directed maintenance. Dhillon (2002), on the other hand, has grouped maintenance into three types based on the underlying motivation for maintenance. According to him, maintenance can therefore involve preventive (i.e., planned, periodic, and specifically-scheduled maintenance work), corrective (i.e., unscheduled maintenance or repair work) and predictive maintenance (i.e., modern measurement and signal-processing methods to accurately diagnose the item/equipment condition during operation).

Maintenance is important not only to ensure dependability but to reduce the cost of operation throughout the systems' life and for accident prevention. Thus, maintenance is also performed to increase safety since incorrect maintenance performances can cause extensive losses (Holmgren, 2005; Mobley, 1990). Previous studies have typically identified human performance as the threat to post-maintenance reliability. However, as Lind (2008) has pointed out, it should be presumed that industrial maintenance operations can also include several risks for the maintenance worker, which should be examined and managed.

3. RISKS IN INDUSTRIAL MAINTENANCE

Maintenance operations include repairs, inspections, preventive maintenance, calibrations and testing as discussed in Section 2. Further, maintenance may include work that is performed in exceptional conditions such as when high priority repairs are carried out while machines are still running or in operation (Nag and Patel, 1998). Thus, maintenance operations may include risks to the machinery, the company and the human carrying out operations (Lind *et al.*, 2008). This section therefore discusses the maintenance-related risks and hazards and their sources.

3.1. RISKS AND HAZARDS

Risk can have different meanings. For example, risk can be defined as the probability or likelihood that someone will be harmed by a hazard (Barnard, 1998; Lind *et al.*, 2008). Occupational Health and Safety Advisory Services (OHSAS) (2008) defined risk as the product of the probability of a hazard resulting in an adverse event multiplied by the severity of the event. Alexander (2000) has further expanded the scope of the term ‘risk’ by describing it as not only a hazard but as an unsafe practice, a peril capable of being insured or a statistical probability. However, regardless of their contradictions and limitations, most definitions suggest that risk is simply the probability of a hazard happening.

In risk management, the term "hazard" is used to mean an event that could cause harm (BS 8800, 2004). Hazards are sources of potential harm to human health, property or environment, which may, under certain conditions, lead to accidents (Lind *et al.*, 2008). In general, accidents often happen suddenly and unexpectedly causing immediate injuries and losses (OHSAS 18002, 2000; British Standard 8800, 2004). On the other hand, many health problems may also develop slowly over time (Lind *et al.*, 2008). Accidents can also be seen to be an organisational problem (Booty, 2006). Supporting this view, some scholars have looked at accidents as the outcome of unsafe actions, error-provoking conditions, and organisational factors (Reason, 1997 cited Lind *et al.*, 2008).

Thus, owing to the diversity in work tasks and working environments, industrial maintenance operations can be challenging. However, in addition to risks that are connected with industrial working environments, maintenance operations also include several maintenance-specific risks (Lind, 2008) which will be discussed in Section 3.2.

3.2. MAINTENANCE-RELATED RISKS

Maintenance is associated with a range of management processes, such as safety management, environment management and quality management as discussed in Section 3.1. When it comes to managing safety and environmental impacts in industry, the role of successful and effective maintenance is important because of the very high demands and expectations for retaining a system’s inherent safety (Edwards, 2005). Further, reliability is also important for environmental safety as failures and accidents in high-risk industries such as the chemical industry can cause major environmental impacts (Acosta and Siu, 1993 cited Lind, 2009; Aneziris *et al.*, 2010). Thus, from a task-based perspective, industrial maintenance poses several risks for the maintenance worker (Lind *et al.*, 2008).

Studies by Lind (2008) and Lind and Nenonen (2008) have grouped maintenance-related accidents under two categories as fatal and severe non-fatal accidents. The most typical type of fatal accidents in industrial maintenance involves falling, and accidents caused by falling objects. In the case of severe non-fatal accidents, the types of accidents are the same. Lind (2008) also regarded fatal accidents as generally involving the working environment and structures while severe non-fatal accidents involve machinery or devices.

A recent study by Lind (2009) further argues that risks in maintenance can be divided into three categories as organisational risk factors, local workplace risk factors and unsafe acts. According to Lind (2009), there are fewer organisational factors and unsafe acts compared to local workplace risk factors. The most typical risks, as revealed by this study, involve physical ergonomics as demonstrated in Table 1.

As Table 1 shows, the risks included are actual hazards such as unsafe working surfaces and error-provoking conditions such as missing or misleading operational safety bulletins or green-painted fields, which can contribute to unsafe acts and, thereby, indirectly undermine maintenance safety. Unsafe acts can arise during task planning and execution and also due to organisational risk factors such as management and supervision.

Table 1: Risks in Maintenance (Source: Lind, 2009)

Organisational Risk Factors	Local Workplace Risk Factors	Unsafe Acts
▪ Pressure of time ▪ Defects in customer corporation ▪ Aging of skilled maintenance crew members ▪ Working on changing sites ▪ Large variety of maintenance tasks	▪ Unsafe walking/surfaces, slipping, tripping, falling ▪ Missing safeguards or shields ▪ Missing/misleading operational safety bulletins ▪ Cold or hot objects ▪ Falling objects ▪ Working outdoors ▪ UV radiation ▪ Lack of oxygen ▪ Site-specific safety challenges and requirements ▪ Defects in the working environment ▪ Working on changing sites	▪ Non-use of Personal Protective Equipment (PPE) ▪ Conscious / unconscious risk-taking ▪ Risks relating to ergonomics (heavy lifts/ carrying too much weight, poor working postures) ▪ Poor safety attitudes

It is well known that the most effective way to improve safety performance is through the prevention of accidents and through reducing uncertainties before accidents happen (Cooke, 1997; Gambatese *et al.*, 2008). This makes safety risk analysis the foundation upon which safety management is built and makes risk assessment a crucial task in a safety management system (Longford *et al.*, 2000; Jung *et al.*, 2008). The next section therefore discusses risk assessment in the industry.

4. Risks Assessment in Industrial Maintenance

Risk assessment includes both hazard identification and estimation of the probability and expected consequences of the observed hazard (Lind and Nenonen, 2008). Risk assessments have traditionally been based on the identification of hazards in the workplace (Lind *et al.*, 2008). However, according to Booty (2006), risk assessment is not merely a tool to calculate the probability and expected consequences of a hazard; it is also the phase in which the appropriate actions to minimise the probability of risk occurrence is determined and the cost of resource allocation to manage the impact of the harm, in the event of its occurrence, is established.

In general, risk assessment should consist of hazard identification, evaluation of preventive safety measures and their functionality, estimation of exposure to the hazards, and the evaluation of consequences and tolerability of the risk (Booty, 2006; BS 8800, 2004) since risk assessment serves as a basis for controlling intolerable risks.

5. Methodology

The study resorted to the case-study method in order to study safety risk assessment in industrial maintenance. Hence, the unit of analysis of the study will be 'risk assessment in industrial maintenance'. Three multinational manufacturing organisations where the products were fast-moving goods were selected for the study based on access and time limitations. Interviews were the primary data collection technique in this study while archival records supplemented data-gathering efforts. Content analysis and cognitive-mapping techniques were used to draw conclusions (See Table 2).

Table 2: Details of Cases

Organisation	Case A	Case B	Case C
Type of Manufacture	Fast-moving consumer goods	Fast-moving consumer goods	Fast-moving consumer goods
Scale of the Organisation	Multinational Organisation	Multinational Organisation	Multinational Organisation
Interviewees	Supply Chain Manager	Supply Chain Manager	Supply Chain Manager
	Environmental Health and Safety Manager (EHS)	Environmental Health and Safety Manager	Environmental Health and Safety Manager
	Maintenance Engineer	Engineering Manager	Maintenance Engineer

6. RESULTS

6.1. MAINTENANCE-RELATED RISKS

The empirical data gathered reveals several maintenance-related risks: namely, management-related risks, workplace-related risks and unsafe acts. These will be discussed in the following section.

6.1.1. MANAGEMENT-RELATED RISKS

The empirical data reveals management of work-related issues such as pressure of time and workload can be identified as risks. A majority of the interviewees said that when people work under pressure they tend to overlook or omit crucial aspects which can result in the occurrence of hazards. Thus, although the pressure of time is not a significant risk in itself, it could cause cognitive overload in workers in the long run. But it could also increase the magnitude of hazard of the existing risks and even create new ones such as workers resorting to inappropriate methods or shortcuts when working under pressure to perform or complete a task on time. Thus, both work planning and resource allocation play essential roles in preventing accidents during maintenance. For example, the Maintenance Engineer of Case A stated "*more errors can happen when the workers are in a hurry*." In the words of the EHS Manager in Case B, "*once we had a unplanned breakdown of a machine and the whole maintenance staff had to work twenty four hours to get it fixed so that the production would not be delayed. During this time two of our workers cut their arms and got badly injured. What they said was the blade slipped from their hand when they hurried to cut the metal pipe*." Therefore, pressure of time can be considered a risk to maintenance workers.

6.1.2. WORKPLACE-RELATED RISKS

The local workplace-related factors often relate to insufficient system- or workplace-maintainability such as factors impeding maintenance task execution. In addition, various site-specific risks, along with the organisation's safety demands, form a group of challenges to the workers. The local workplace factors can also include outdoor conditions such as weather and other environmental conditions such as temperature, humidity, etc.

With regard to maintenance-related risks, the empirical data revealed that bruises and minor cuts were the most frequent during the maintenance process. Mostly, the accidents occurred work was in progress or when working at the workshop during the day. According to the Maintenance Engineer of Case A, "*these cuts and bruises are not even considered as first-aid injuries*." However, there were situations when near-fatal outcomes did occur. EHS Manager of Case A cited an example: "*an employee who worked on the* *roof of the building had got into contact with a high tension electric cable and almost died*." The EHS Manager of Case B cited a fatal accident: "*a 45-year-old worker was crushed by a pallet falling from a vehicle tail-lift. He was helping a driver to unload a pallet from a lorry when the load fell on top of him*." Thus, the empirical data on maintenance-related risks consists of a majority of workplace-related risk factors. As the Maintenance Engineer of Case A stated: "*we cannot ignore anything as not being a risk, Due to uncertainty, any workplace factor can turn out to be a risk to health and safety*." Therefore, local workplace-related risk factors have a significant impact on the safety of maintenance workers.

6.1.3. UNSAFE ACTS

From the three categories identified as maintenance-related risks, unsafe acts are the most dangerous. According to the empirical findings, unsafe acts can be risks as well as causes of risks. For example all three interviewees in Case A cited the example of a godown being opened after two days of fumigation although it is a must that the godown be closed for at least three weeks after fumigation. This in fact caused some of the employees to collapse due to inhalation of poisonous gases. As the EHS Manager of Case A pointed out: "*because of disregarding the standard operating procedures and non-use of PPE the employee received injuries though their lives were saved*." Thus, disregarding the standard operating procedures and the non-use of PPE not only caused a chemical risk, but also led to near fatal injuries. This shows how unsafe acts can cause risks as well as be a risk in itself.

Based on the empirical data, the risks in industrial maintenance can be tabulated (See Table 3) in the following manner.

Table 3: Summary List of Risks

Management Related Risks	Workplace Related Risks	Unsafe Acts
▪ Pressure of time ▪ Work load	▪ Physical hazards ▪ Environmental conditions ▪ Biological hazards ▪ Chemical hazards ▪ Electrocution ▪ Missing safe guards ▪ Lack of oxygen ▪ Cold /hot objects ▪ Fire ▪ High pressure air and fluid	▪ Non-use of PPE ▪ Conscious/unconscious risk-taking ▪ Ergonomics risk ▪ Defects in safety attitudes ▪ Ignoring work instructions ▪ Disregarding Standard Operating Procedures (SOP) ▪ Negligence

6.2. SAFETY RISK ASSESSMENT METHODS USED

Several risk assessment methods have been designed for industrial workplaces. However, these methods typically focus on general working environment hazards or are designed for a certain process or specific equipment. These methods can be either qualitative methods or quantitative methods. Further, different methods were used for specific types of risk identification and risk analysis as shown in Table 4. These will form the basis for the following discussion.

All the interviewees stated that they did not have a particular risk assessment procedure for industrial maintenance. However, in all three cases, risk assessment methods were practiced which were applicable to the whole organisation. In this section, the empirical data relevant to the types of safety risk assessment methods identified will be discussed. The risk assessment methods used can be discussed under two headings: methods used to identify risks and methods used to analyse the risks (Table 4).

Table 4: Methods Used in Risk Assessment

Risk Identification Methods	Case A			Case B			Case C		
	SCM	EHS	ME	SCM	EHS	MM	SCM	EHS	M E
Checklists	√	√	√	√	√	√	√	√	√
Brain-storming	√	√	√	√	√	√			
Decomposition Technique	√	√	√	√	√	√			
Root-cause Analysis							√	√	√
Semi-structured Interviews							√	√	√
Risk Analysis Methods	**Case A**			**Case B**			**Case C**		
	SCM	EHS	ME	SCM	EHS	MM	SCM	EHS	M E
Risk Calculator (Semi-Quantitative)	√	√	√						
Risk-rating Matrix (Qualitative)				√	√	√			
Risk-rating Matrix (Semi-Quantitative)							√	√	√
SCM - Supply Chain Manager ME - Maintenance Engineer MM - Maintenance Manager EHS – Environmental Health and Safety Manager									

6.2.1. METHODS USED FOR RISK IDENTIFICATION

In all three organisations, the first step in risk assessment would be to identify the risks because an unidentified risk cannot be managed effectively other than in a reactive way.

- ***Checklists***

All the interviewees said that they used checklists for identifying the risks. According to the EHS Manager of Case A, "*we use experiences from past incidents to make a check list of risks*." For example, the Maintenance Engineer of Case A stated that "*we use the check-lists to identify hazards and risks or to assess the effectiveness of controls. They can be used at any stage of the life cycle of a product, process or system. They may be used as part of other risk assessment techniques but are most useful when applied to check that everything has been covered*." Thus, checklists can be identified as the simplest form of identifying hazards, risks or control failures. These have been developed usually from experience, either as a result of a previous risk assessment or as a result of past failures.

- ***Brainstorming***

As per empirical data, brainstorming is another popular method for identifying the risks. For example, the Supply Chain Manager of Case B stated that "*for brainstorming we used a team of people with knowledge of the organisation, system, process or application being assessed. Normally this technique is used when assessing the risk involved in implementing something new like a Building Management System*." Thus, it is used in high-level discussions where issues need to be identified for a more detailed review of a particular problem.

- ***Decomposition Technique***

At the same time, the empirical data shows that decomposition techniques are also useful in identifying risks. For example, the EHS Manager in Case B stated that "*whenever we do a maintenance activity, let's say replacing a pipe, we breakdown that process into small tasks and, for each task, the potential risks involved are identified*." Therefore, decomposition techniques allow risks to be identified in a structured manner.

- ***Semi-structured Interviews***

The empirical findings suggest that semi-structured interviews can also be used to identify risks. For example, the EHS Manager of Case C stated that "*having a brainstorming session is very difficult as it is difficult to bring the members together. So we carry out semi-structured interviews*." The Maintenance Engineer of Case C further stated that "*we prepare a set of questions as a guide and appoint a suitable person to carry out the interviews and gather the relevant data*." Thus, semi-structured interviews can be used as input to risk assessment.

- ***Root-cause Analysis***

The empirical data from case-studies also showed that root-cause analysis can be used to identify the root or original causes of an incident instead of dealing only with the immediately obvious symptoms. For example, the Supply Chain Manager of Case C stated that they used root-cause analysis for accident investigation. "*Once there was a fire in one of our labs. To identify what was the cause of it we used root-cause analysis*." Thus, root-cause analysis can be used as a reactive risk identification technique.

Thus, the empirical data shows that there are various risk-identification methodologies available to help organisations to identify risks. The findings show checklists, brainstorming and decomposition techniques to be the most widely used risk identification techniques. Further, checklists are used in conjunction with either the brainstorming or decomposition technique. However, the empirical findings also show that root-cause analysis and semi-structured interviews can also be useful in identifying risks.

6.2.2. METHODS USED FOR RISK ANALYSIS

Once a risk is identified, it is analysed and evaluated with the aim of prioritising the identified risks for further actions. According to the empirical findings, the most widely used risk analysis method is the risk rating matrix. As the Maintenance Manager of Case B stated, "*in our organisation we use the risk rating matrix for identifying the likelihood of occurrence, the consequence of the risk event and the level of risk. If we take a person falling from a ladder, the probability of occurrence is likely. The consequence of the risk maybe major because the employee can get injured. So the level of risk is very high. Here we use relative measures rather than numerical values*." Therefore, the risk rating matrix allows those responsible for risk management to determine the severity of the risk of an event.

However, the empirical findings also showed that some organisations prefer the use of weightings to determine the probability and consequence labels. For example, the EHS Manager of Case C said that "*they prefer defining the consequence labels as a percentage of the project or activity cost and the probability as a percentage*." Their reason for using such a method was to eliminate the bias created through the use of relative measures. For example, the Maintenance Engineer of Case C stated that "*the relative measures vary according to the experiences, knowledge and attitudes of the decision maker; however, with the weightings, we can reflect the relative magnitude of probability and consequences and it is consistent for all projects*." Therefore, risk rating matrixes are used in qualitative as well as semi quantitative analysis.

At the same time, the empirical findings also showed that risk levels can be calculated on the basis of Probability/Likelihood, Exposure and Consequences using the risk calculator. For example, the EHS Manager of Case A stated that "*the risk calculator illustrates the probability, exposure to hazard in percentage of time, consequences and the risk level. Once the inputs for probability, exposure to the hazard in percentage of time, 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.

Prevention of accidents is based on risk analysis. According to the empirical findings reported above, it involves the identification of the hazards and the consequences and the likelihood of occurrence of each hazard. Based on these findings, the most preferred method for capturing the nature and degree of risk in industry is the semi-quantitative analysis. Hence, the risk calculator and the semi-quantitative risk rating matrix can be identified as the most preferred methods of risk analysis.

7. CONCLUSIONS

This study adopts the case-study approach in order to demonstrate what the risks and risk assessment methods are in industrial maintenance in Sri Lanka. The empirical data showed that maintenance-related risks consist of a majority of workplace risks and a fewer number of management related risks and unsafe acts. However, from the three categories of identified maintenance-related risks, unsafe acts are the most dangerous because the empirical findings show unsafe acts to be both risks as well as causes of risks.

The risk assessment methods identified in the empirical findings can either be qualitative methods or quantitative methods. Moreover, the risk assessment methods used can be discussed under two headings: namely, methods used to identify risks and methods used to analyse risks. While risk identification methods consist of qualitative methods, risk analysis methods consist of qualitative as well as semi-qualitative or quantitative methods.

These findings from the Sri Lankan manufacturing industry show that various risk-identification methods are used to help the organisations identify risks. The findings show checklists, brain-storming and decomposition techniques to be the most widely used risk identification techniques. It was also revealed that these techniques are mostly used for their simplicity and for their ability to identify risks in a broader sense. However, the empirical findings also show that the root-cause analysis and semi-structured interviews can also be useful in identifying risks. While the root-cause analysis is used for reactive risk identification, the other methods are used for proactive risk identification.

The prevention of accidents is based on risk analysis which involves the identification of the hazards, and the consequences and likelihood of the occurrence of each hazard. Semi-quantitative analysis is the most preferred method for expressing risk in industry. Hence, the risk calculator and the semi-quantitative risk rating matrix are used as the most preferred methods in risk analysis. Further, qualitative risk rating matrixes are also used. The reason for the use of a semi-quantitative risk rating matrix and risk calculator over the qualitative risk rating matrix is that qualitative measures can vary according to the experiences, knowledge and attitudes of the decision makers. In semi-quantitative analysis, on the other hand, the relative magnitude of probability and consequences can be reflected with the use of weightings and it is consistent for all projects.

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