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Risk Assessment and Management In A Manufacturing Industry

Nithin.M[1], Gokulachandran.J[2]
M.Tech. Student[1], Department of Mechanical Engineering,
Amrita School of Engineering
Associate Professor[2], Department of Mechanical Engineering,
Amrita School of Engineering
Amrita Vishwa Vidyapeetham, Coimbatore –641112, Tamilnadu – India

Abstract

An industry is always prone to hidden risks. This study provides an overview on the identification, assessment and management of risks in a manufacturing industry. A conceptual model was developed for the effective Risk Management. A case study was performed for Risk identification through observation and interview with company personnel and Risk assessment by a) Risk classification and b) Risk prioritization using Analytical Hierarchy Process (AHP). Suggestions for risk control were also put forward to the company along with the conceptual model. In this study, suggestions were also made to document the Risk identification, Risk assessment, and Risk control continuously for every update. The suggestions for effective risk control, were made based on the severity of each risk and cost effectiveness.

Keywords: Risk management, Analytical Hierarchy Process (AHP), Risk Identification, Risk Prioritization

Introduction

Risk management is an essential part of every manufacturing industry for the prevention of accidents which may affect the workers, operations and the environment. It is done through three general steps- Risk identification, assessment, and control. Risk identification is always considered as the main practice among these three steps which helps to surface the hidden risks in the industries.

A risk can be defined as the possibility of happening an unexpected incident and it is always possible only to control it, not to eliminate. Risk may effect task execution, increase the production cost, cause huge economic loss, social impact, product damage, product delays and personal injury [1]. The risk management actions have to be revised and reorganized intermittently in the manufacturing industries because of

the frequent installation of new equipments, recently appointed workers and newly developed ways of operations. The steps to be followed for the effective risk management in a manufacturing industry are: Risk identification through keen observation and interview with the company personnel, Risk assessment with the help of some mathematical tools, and Risk control by the effective utilization of resources to reduce, screen and control the likelihood and effect of unexpected happenings.

Present study concentrates on the development of a conceptual model for the effective risk management in a manufacturing industry. The case study was executed in a cleaning equipment manufacturing industry by conducting identification of Risks through inspection and interview with company personnel. The assessment of risks was done by Risk classification and Risk prioritization using AHP. Ideas for risk control was also submitted to the company along with the conceptual model. Literature review is presented in Section II.

Literature Review

Alfredo Federico Serpella et al, [2] defines risk as the possibility of a damaging event happening in the task, affecting its goals. Perera. J and Holosomback. J [3] describes that the purpose of risk management is to detect what can go wrong, how likely it is for these to happen, and what are the consequences if they were to happen. G. Y. Zhao et al, [1] indicates that the concept of risk management was originated in Germany, and has become a complete boundary science and significant branch of modern management science in last 20 years. At present, it has been usually applied to all respects of activities in the society, including technical risk, equipment quality risk, reliability engineering, financial and economic decision making, etc. A recent study on the risk management methodology covering the entire product cycle was performed by Jan Machac et al[4], which explains Risk management as an essential part of every manufacturing industry because running industries always goes with several types of risks. Appropriate risk management practice focuses on the identification and controlling of risks, it increases the probability of success and decreases the probability of failure as well as uncertainty in attaining of over-all objectives of the industries [4].

Liping Liu et al, [5] believes that it's important to detect the significant risks and more attention should be there for selecting proper methods to assess those risks according to the features of the selected industry. They also represent a conceptual model which describes the procedure to be followed for the effective risk management in a chemical industry supply chain along with the details of risk assessment done by using Analytical Hierarchy Process (AHP).

The Analytic Hierarchy Process (AHP) is a decision-making approach and was introduced by T.L. Saaty [6]. AHP became the important tool of many research scholars mainly due to the fine mathematical properties of the technique and the fact that the necessary input data are rather easy to obtain [7]. Identification and assessment of risks in an EPC (Engineering, Procurement and Construction) project was described by Ning Yu et al, [8] which gives an outline of risk assessment by using the Interpretive Structural Modelling.

Conceptual Model

In a manufacturing industry, risk management may be divided into seven categories and they are represented in this conceptual model as a feedback loop or a cyclic process. The seven categories represented in this conceptual model are A) Individual Unit Features, B) Risk Identification, C) Risk assessment, D) Suggestions for Risk Control, E) Risk Documentation, F) Display risk documents in the company, G) Review and update periodically.

A. Individual Unit Features

A typical manufacturing industry may consist of several units like manufacturing, assembly, stores etc. For the successful risk identification and management, the working environment, types of equipments and operations used, attitude of the employers have to be analyzed. Any such feature can be identified as individual unit features.

B. Risk Identification

Effective Risk Identification is always essential to identify the key risks in the company, drivers of these risks and their consequences. Risk identification in a company can be done through observation and interview with the company personnel.

C. Risk Assessment

Risk Assessment consist of two steps. i.e. Risk classification and Risk prioritization using AHP (Analytical Hierarchy Process). The identified risks may be classified into human risk, operational risk, environmental risk, financial risk, supply risk, etc. After the classification, the identified risks have to be prioritized in order to decide which risk should be managed first.

D. Suggestions for Risk Control

For the effective risk control, suggestions have to be made based on the severity of each risk and cost effectiveness. Suggestions have to be made in the order of prioritization of each risk after getting the numerical priority value for every risk by using AHP.

E. Risk Documentation

According to the section 20 of the Health and Safety Act, an organization should prepare risk documents which includes all the activities that the company has done for the effective risk management [9]. In this study, suggestions are made to produce documents for every update on Risk identification, Risk assessment, and Risk control continuously.

F. Display Risk Documents In The Company

Based on the Health and Safety Act-2005, safety statement, which consist of the risk assessment details, is brought to the attention of all the workers at the workplace[9]. The safety statement must be in a format and language such that all the workers in the plant can understand the risk management activities performed in the company

recently and thereby making awareness to the newly appointed workers regarding the precautions to be taken for the effective monitoring of hazards.

G. Review and Update Periodically

Safety statement must be reviewed and updated periodically whenever new changes has been made in the company, i.e., appointment of new workers, installation of new equipments and the implementation of latest way of operations.

A Health and Safety Authority inspector may analyze the safety statement during an examination of the workplace. If the inspector finds that it is insufficient or not given the details of risk assessments for activities presently going on during the inspection, he or she can suggest to analyze and update safety statement within 30 days [9].

After reviewing and updating the risk activities in the company, the process of analyzing individual unit features have to be started there by continuing the cyclic process of risk management. A conceptual model for the effective risk management used in this study is given in Fig-1. A case study is given in the next section.

Case Study

A case study was carried out in a cleaning equipment manufacturing industry which produces cleaning equipments for industrial, commercial and domestic applications. The plant comprises of mainly four sections specifically Manufacturing Department, Assembly Unit, Reliability Lab, and Store. Analysis of operations in each section was carried out effectively in order to identify the possibility of occurring unexpected events in each and every operation.

A. Risk Identification

Risk Identification is the detection of risks which may influence the project and recording their characteristics [10]. Most of the risks in the manufacturing industries are always hidden. Keen observation and interview with the experienced company persons are always necessary for the precise and perfect identification of risks related to workforce, equipments, operations and the environment. Consequences related to each of the risk and vulnerabilities to the identified risks have to be found out. Accurate and complete "Risk Identification" is mandatory for effective Risk Management. The identified risks and their consequences are given in Table-1.

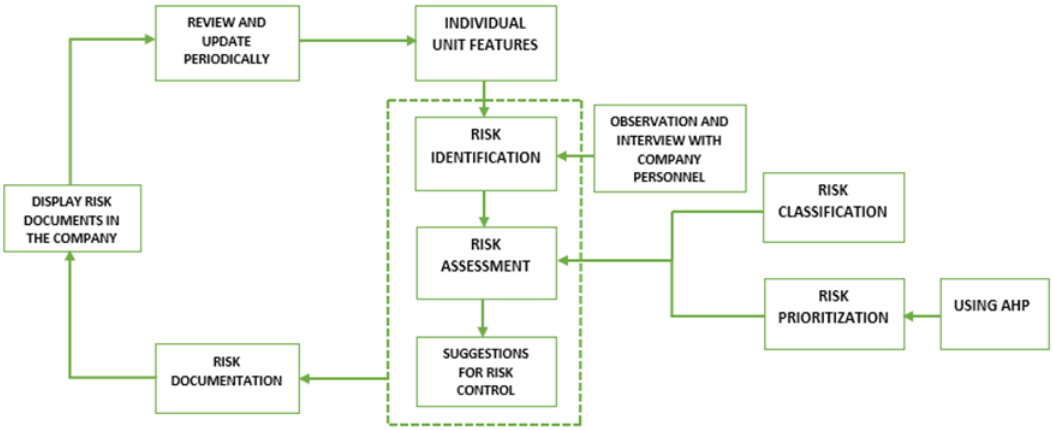

Figure 1: Conceptual Model

Table 1: Identified Risks and Their Consequence

Identified Risks	**Consequences**
1. No separate walkway for both the pedestrians and forklift trucks 2. Unawareness among the employees about the "emergency safety zones" 3. Current utilization of mercury manometer for vacuum motor checking	• Health hazards to the employees by fort lift trucks • Unorganized people extraction during complex emergencies or natural disasters • Mercury is a hazardous and banned material
4. Interrupted testing sequence for machine 5. Current process operation for press breaking by single leg activated pedal switch may yield bad quality in case of two men operation 6. Pneumatic hose line hinders the movement of the workers	• Product damage • Leads to delays • Demand dissatisfied • High profit loss • Decreased production rate
7. Placing an ignition source(Batteries) in an explosive atmosphere 8. Lack of screens in welding area 9. Fumes generated during welding	• Contaminated Air • Explosion • Government penalty • Reputation damage • Welding radiation and spatter

B. Risk Assessment

Risk assessment is a careful inspection of what, in the workplace, could cause damage to people, so that the workers can weigh up whether he or she has taken adequate precautions or should do more to prevent damage [9]. After risk identification is

completed, the key risks identified in each section have to be assessed such that probability of the harm to occur, consequences related to that harm and vulnerabilities to the same can be estimated. Based on these estimations, the company persons will be able to check whether enough precautions are taken to prevent the harm or should do more. In this study, the two main categories of risk assessment are Risk classification and Risk prioritization.

1) Risk Classification

The identified risks are broadly classified into three: Human Risk, Operational Risk, and Environmental Risk. The detailed information of Risk classification is given in Table-2.

2) Risk Prioritization

After classifying the risks, Risk prioritization have to be done to complete the risk assessment. The tool used here for the risk prioritization is the Analytical Hierarchy Process (AHP).

Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process was developed by T. L. Saaty in the 1970's[6]. By using the Analytical Hierarchy Process (AHP), Numerical priority for each of the decision alternatives employed in an industry can be calculated. By using AHP, numerical priority will be more for the suitable decision with respect to the objective and is not based on the correctness of the decision alternative. The input data required for the AHP prioritization are prepared by the experienced persons in the industries based on the situation, type of operation, nature of the equipments and workforce.

In this study, AHP was used for prioritizing the categories and individual risk. A fundamental scale is used in making the comparison. It consists of verbal judgments ranging from equal to extreme (equal, moderately more, strongly more, very strongly more, and extremely more), Numerical judgments (1, 3, 5, 7, 9) are made with respect to the verbal judgments and compromises between these numerical values [6]. The AHP Ranking scale used to design the comparison matrices is given in Table-3.

Table 2: Risk Classification

Category	**Identified Risks**
Human Risk	• No separate walkway for both the pedestrians and fort lift trucks • Unawareness among the employees about the "emergency safety zones" • Current utilization of mercury manometer for vacuum motor checking
Operational Risk	• Interrupted testing sequence for machine • Current process operation for press breaking by single leg activated pedal switch may yield bad quality in case of two men operation

	• Pneumatic hose line hinders the movement of the workers
Environmental Risk	• Placing an ignition source(Batteries) in an explosive atmosphere • Lack of screens in welding area • Fumes generated during welding

Table 3: AHP Ranking Scale

Numerical Ranking	**Preference**
9	Extreme
7	Very Strong
5	Strong
3	Moderate
1	Equal
2,4,6,8	Intermediate Values

From the comparison matrix designed, the normalized matrix is defined which will give the percentage of priority for every risks. This tool also includes the method of checking the consistency of the results by calculating the consistency ratio (CR).

AHP-Procedure

1. Designing a comparison matrix based on the fundamental scale (Table-3) with the help of a company personnel
2. Defining the normalized matrix through the normalization of each column of the comparison matrix
3. Finding the arithmetic average of numerical values in each row of the normalized matrix in order to compute the weightage criteria for each risk
4. Checking the consistency of the obtained result by calculating the consistency ratio (CR)
5. Consistency Ratio (CR)= Consistency Index (CI) / Random Index (RI)
   - Consistency Index (CI) = $(\lambda max - n) / (n - 1)$
   - Priority Row (λmax) = Sum of [Priority Vector of each row * Column wise total of the comparison matrix]
   - Forming a new column (Priority Vector) by calculating the n'^{th} root of the product of numerical values in each row and to get the sum of this new column (n= size of the comparison matrix)
   - Random Index (RI) is to be selected from the Random Index table [11] (Table-4).

Table 4: Random Index Table

n	1-2	3	4	5	6	7
RI	0	0.58	0.90	1.12	1.24	1.32

The comparison matrix, normalized matrix, and the consistency results for the 'Types of risks' is given in the next section.

Comparison Matrix for 'Types of Risks'
A comparison matrix is designed by assigning ranks to each type of risk. The rankings are given by the company personnel based on their experience and knowledge. Three matrices were designed with the help of company persons in order to get a valid result and a final comparison matrix is formulated based on the average of these three matrices. The comparison matrix for the 'Types of Risks' is given in Table-5.

Table 5: Comparison matrix for 'Types of Risks'

	Operational Risk	**Human Risk**	**Environmental Risk**
Operational Risk	1	0.111	0.142
Human Risk	9	1	3.333
Environmental Risk	7	0.344	1
TOTAL	17	1.45	4.47

Normalized Matrix for 'Types of Risks'
Normalized matrix is defined on the basis of the comparison matrix designed, which will give the percentage of priority for every risk. Firstly, the column wise total of the comparison matrix calculated and each of the element in the matrix is divided by the corresponding column wise total in order to design the normalized matrix. By taking the average of each row, the percentage of priority for each type of risk is calculated. The average value (weightage criteria) is multiplied by 100 to get the percentage of priority (For e.g. percentage of priority of operational risk: 0.055×100= 5.5 %). The Normalized matrix for 'Types of Risks' is given in Table-6.

Table 6: Normalized Matrix for 'Types of Risks'

	Operational Risk	**Human Risk**	**Environm-ental Risk**	**Avg. (Weightage Criteria)**
Operational Risk	0.058	0.076	0.031	0.055
Human Risk	0.529	0.687	0.744	0.653
Environm-ental Risk	0.411	0.236	0.223	0.290

Consistency Ratio Calculation for 'Types of Risks'
AHP also includes the method of checking the consistency of the results by calculating the consistency ratio (CR). We can accept the priority weightage of each

factor if the consistency ratio is significantly small (about 10% or less) [6]. The consistency ratio calculation for the 'Types of Risks' is given in Table-7.

Since the consistency ratio is 0.05 which is less than 0.10, it is verified that the data obtained is consistent. Similar to above steps, the priority and consistency of the risks belonging to each type are identified. The priority percentage of each type of risk are illustrated in Table-8.

Analytical Hierarchy Process (AHP) –Results

The results are tabulated after doing the prioritization by using AHP. The following table of results includes the ranking given for categories and individual risk according to its priority and percentage of priority of the same. Calculated AHP results are shown in Table-8, 9, 10 and 11.

Table 7: Consistency Ratio calculation for 'Types of Risks'

	Operational Risk	**Human Risk**	**Environmental Risk**
Operational Risk	1	0.111	0.142
Human Risk	9	1	3.333
Environmental Risk	7	0.344	1
Column wise Total	17	1.45	4.47
Priority Row	0.850	0.957	1.251

Consistency Ratio= 0.05

3rd Root of Product	**Priority Vector**
0.2466	0.05
3.1071	0.66
1.3403	0.28
TOTAL=4.694	

Table 8: AHP Result for 'Types of Risks'

Types of Risks	**Percentage of Priority (%)**	**Rank**
Human Risk	65.3	1
Environmental Risk	29.0	2
Operational Risk	5.5	3

Table 9: AHP Result for 'Human Risks'

Type of Risk	**Identified Risks**	**Percentage of Priority (%)**	**Rank**
Human Risk	Current utilization of mercury manometer for vacuum motor checking	68.8	1
	No separate walkway for both the pedestrians and fort lift trucks	21.6	2
	Unawareness among the employees about the "emergency safety zones"	9.4	3

Table 10: AHP Result for 'Environmental Risks

Type of Risk	**Identified Risks**	**Percentage of Priority (%)**	**Rank**
Environmental Risk	Fumes generated during welding	56.7	1
	Placing an ignition source(Batteries) in an explosive atmosphere	32.4	2
	Lack of screens in welding area	10.6	3

Table 11: AHP Result for 'Operational Risks'

Type of Risk	**Identified Risks**	**Percentage of Priority (%)**	**Rank**
Operational Risk	Current process operation for press breaking by single leg activated pedal switch may yield bad quality in case of two men operation	67.5	1
	Pneumatic hose line hinders the movement of the workers	23.1	2
	Interrupted testing sequence for machine	9.2	3

C. Suggestions for Risk Control

The practical elimination of risks is impossible because of the natural uncertainty of input variables; however, risk management allows us to reduce the risk to the level that we are ready to accept [12]. In this study, along with the conceptual model, suggestions for the effective control of the identified risks are also forwarded to the company. These suggestions are made based on the severity of each risk and cost effectiveness. Identified risks, their classification and the suggestions for effective control of corresponding risks are shown in Table-12. The 'Types of Risks' and 'Identified Risks' are arranged according to the order of prioritization in the table.

Table 12: Suggestions for Risk Control

Rank	Classification	Identified Risks	Suggestions For Risk Control
1	**Human Risk**	1. Current utilization of mercury manometer for vacuum motor checking 2. No separate walkway for both the pedestrians and fort lift trucks 3. Unawareness among the employees about the "emergency safety zones"	• Mercury manometers should be replaced by Digital manometers • Separate walkway with crossings should be provided for the pedestrians • One large "Factory site plan" showing emergency safety zones should be displayed everywhere in the company
2	**Environmental Risk**	Fumes generated during welding 1. Placing an ignition source (Batteries) in an explosive atmosphere 2. Lack of screens in welding area	• Some effective welding fumes extraction machines must be installed inside the plant • Batteries should be stored separately • Screen should be provided for every welding area
3	**Operational Risk**	1. Current process operation for press breaking by single leg activated pedal switch may yield bad quality in case of two men operation 2. Pneumatic hose line hinders the movement of the workers 3. Interrupted testing sequence for machine	• Double leg activated pedal switch should be provided for the press-break operation • To optimize the length of pneumatic hose line • To paint "No Entry" caution mark along the circumference of the test machine

Conclusions

In this paper, a model for the effective risk management was developed and the risk identification was carried out through examination and interview with the company persons. The identified risks were classified into three categories- Human Risks, Environmental Risks and Operational Risks. Risk prioritization was done with the help of Analytical Hierarchy Process (AHP), and the weightage criteria for the priority of each risk was calculated. Suggestions for the effective risk control according to the priority and cost effectiveness was given to the company along with the conceptual model.

If the critical risks are separated out from the identified risks, the risk control could be done more effectively. Interpretive Structural Modelling (ISM) tool can be applied for this which could be considered as a future work.

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