IDENTIFICATION AND COMPARISON OF ACCIDENTS ON DAM AND HIGHWAY CONSTRUCTION SITES

A

Thesis

Submitted in partial fulfillment of the requirements for the award of the degree

Of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

With specialization in

CONSTRUCTION MANAGEMENT

Under the supervision of

Dr. Saurabh Rawat

(Assistant Professor)

Dr. Ashok Kumar Gupta

(Professor and Head)

And

Dr. Saurav

(Assistant Professor)

By

Akanksha Thakur (162605)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN- 173234

HIMACHAL PRADESH, INDIA

May, 2018

CERTIFICATE

This is to certify that the work which is being presented in the thesis title **"IDENTIFICATION & COMPARISON OF ACCIDENTS ON DAM & HIGHWAY CONSTRUCTION SITES"** in partial fulfillment of the requirements for the award of the degree of Master of technology with specialization in Construction Management and submitted in Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Akanksha Thakur** during a period from August 2017 to may 2018 under the supervisor **Dr. Saurabh Rawat (**Assistant Professor) and co-supervisors **Dr. Ashok Kumar Gupta** (Professor and Head of Department), **Dr. Saurav (**Assistant Professor) Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: -

Dr. Ashok Kumar Gupta
Professor and Head of Department

External Examiner

Dr. Saurabh Rawat
(Supervisor)
Assistant Professor

Prof. Ashok Kumar Gupta
(Co – Supervisor 1)
Head of Department

Dr. Saurav
(Co – Supervisor 2)
Assistant Professor

Acknowledgement

I wish to express my profound gratitude and indebtedness to my supervisor Dr. SAURABH RAWAT (Assistant Professor) and co-supervisors Dr. ASHOK KUMAR GUPTA (Professor and head of department), Dr. SAURAV (Assistant professor), Department of civil engineering, Jaypee University of Information Technology, Waknaghat, for introducing the present topic and for their inspiring guidance, constructive criticism and valuable suggestions for this thesis work.

I would like to express my gratitude to Dr. SAURAV SHRIVASTVA (Software programmer) for helping me to learn fuzzy logic system. I would also like to thank all the faculty and staff of the Department of Civil Engineering Jaypee University of Information Technology, Waknaghat, for their guidance and the support they have provided me. I would also like to thank my parents for their continued support. Thank you for always encouraging and helping me to pursue my dreams.

AKANKSHA THAKUR

(162605)

Abstract

With the strong economic situation in India to promote the vigorous development of the construction industry, the frequency and severity of future accidents at construction sites will inevitably increase. Construction sites are dangerous places that can cause worker injuries/ illness/death. These may be due to electrocution, falling from high places, injuries caused by tools, equipment, and machinery; injuries caused by moving the construction vehicle, manual operations and diseases caused by harmful substances such as dust and chemicals. Every employee has the right to work in a healthy and safety environment.

In the present research work two construction sites which are “National Thermal Power Corporation Limited KOLDAM” and “KIRATPUR-NERCHOWK HIGHWAY” have been taken into account for identification of accidents which have taken place on site in past. The data collections of accidents have been done through quessonnarie forms which include 20 questions based upon most expected accidents. Quessonnarie forms have been filled by various site engineers, engineers, laborers and safety managers. A total of 50 quessonnarie responses have been gathered from each highway as well as dam site. Synthesis of quessonnarie forms has been performed through GUI in order to categorize the various accidents into four classes namely minor, reportable, major and fatal. In dam construction accidents due to access scaffolding, body stressing due to muscular stressing while lifting, carrying objects, accidents in absence of proper personnel protective equipment were classified as reportable and whereas in highway construction accidents due to single or long term contact with chemical and other substances, accidents in absence of higher or concerned authorities were classified as minor, accidents due to using defective equipments or disc cutters, due to sound and pressure were classified as reportable. By applying Fuzzy logic to the accidents categorized as fatal, major, reportable, minor it can be concluded that on both dam & highway construction sites, accidents in absence of personnel protective equipments are found to be the most critical accidents. The comparison of dam and highway sites further reveals occurrences of greater number of accidents at highway site.

Keywords: *Dam, Highway, Personnel protective equipment, Fuzzy logic, Synthesis*

TABLE OF CONTENTS

Certificate……………………………………………………………………………….ii

Acknowledgement………………………………………………………………….....iii

Abstract…………………………………………………………………………….....iv

List of Figures………………………………………………………………………viii

List of Tables…………………………………………………………………………...ix

List of Symbols……………………………………………………………………….x

CHAPTER 1 INTRODUCTION

1.1 General…………………………………………………………………...1

1.2 Types of accidents………………………………………………………..2

1.3 Causes of accidents………………………………………………………3

1.4 Cost of accidents……………………………………………………......5

1.5 Data collection.……………………………………………………………...7

1.6 Models for synthesis.……………………………………………………….7

1.7 Organization of thesis……………………………………………………...11

CHAPTER 2 LITERATURE REVIEW

2.1 General……………………………………………………………………..12

2.2 Accidents during construction……………………………………………..12

2.3 Identification methods for accidents………………………………………13

2.4 Synthesis of data………………………………………………………….. 17

2.5 Fuzzy logic…………………………………………………………………24

2.6 Summary of literature review……………………………………………...30

2.7 Objectives…………………………………………………………………30

CHAPTER 3 METHODOLOGY

3.1General…………………………………………………………………….31

3.2Steps in methodology 31

3.3Material…………………………………………………………………....32

3.3.1 Dam construction……………………………………………………...33

3.3.2 Highway construction……………………………………………………….34
3.4Data Analysis Methods……………………………………………………………36
3.4.1Implementation of synthesis……………………………………………36
3.4.2Implementation of fuzzy logic system……………………………….....40

CHAPTER 4 RESULTS AND DISCUSSIONS
4.1General………………………………………………………………………….46
4.2Synthesis of quessonnarie form………………………………………………...46
4.2.1Various percentages of responses for dam site…………………………46
4.2.2Various percentages of responses for highway site…………………….48
4.2.3Categorization of accidents on dam site………………………………..50
4.2.4Categorization of accidents on highway site…………………………...51
4.3Results of fuzzy logic………………………………………………………….53
4.3.1Results of fuzzy logic for dam site……………………………………..53
4.3.2Results of fuzzy logic for highway site………………………………...55

CHAPTER 5 CONCLUSIONS
5.1General………………………………………………………………………..57
5.2Conclusions…………………………………………………………………...57
5.3 Scope for future work………………………………………………………..58

REFRENCES

APPENDIX

List of Figures

S.No.	Title	Page No
Figure 1.1	Categories of accidents	2
Figure 1.2	Causes of accidents	3
Figure 2.1	Causes of accidents	13
Figure 2.2(a)	Age group of respondents	14
Figure 2.2(b)	Working experience of respondents	14
Figure 2.2(c)	Education of respondents	14
Figure 2.2(d)	Safety training of respondents	14
Figure 2.3	Accidents by gender	15
Figure 2.4	Death cases by gender	15
Figure 2.5	Permanent disability cases by gender	16
Figure 2.6	Simplified measurement model	17
Figure 2.7	Simplified structure model	18
Figure 2.8	Framework of research in construction safety risk	19
Figure 2.9	DfS factors	20
Figure 2.10	Adequacy of accessible DfS guidelines and materials	20
Figure 2.11	DfS Issues faces in practice	21
Figure 2.12	Josang's opinion triangle	23
Figure 2.13	Hierarchical structure of outcome severity level grading	24
Figure 2.14	Representation of OR gate	25
Figure 2.15	Representation of AND gate	25
Figure 2.16	Steps included in fuzzy logic system	26
Figure 2.17	Linguistic variables	27
Figure 2.18	Membership functions for risk	28
Figure 2.19	Sever architecture for risk system	28
Figure 2.20	Analysis framework	29
Figure 3.1	Work Plan in methodology	31
Figure 3.2(a)	JUIT to dam site	32
Figure 3.2 (b)	JUIT to highway site	32
Figure 3.3 (a)	Workers working at height	34

Figure 3.3 (b) Striking of workers with vehicle 34
Figure 3.4 (a) Soil stabilization 35
Figure 3.4 (b) Tunneling process 35
Figure 3.4 (c) Retaining wall 36
Figure 3.4 (d) Tunnel construction 36
Figure 3.5 Sequential diagram for synthesis and fuzzy logic 39
Figure 3.6 Framework of fuzzy logic 41
Figure 3.7 Types of membership functions 42
Figure 3.8 Rule editor 43
Figure 3.9 Rule viewer 44
Figure 3.10 Surface viewer 44
Figure 4.1 Most critical accident on dam site 54
Figure 4.2 Pie chart for dam accidents 54
Figure 4.3 Most critical accident on highway site 55
Figure 4.4 Pie chart for highway site 56

List of Tables

S.No.	Title	Page No
Table 3.1	Respondents of dam site	33
Table 3.2	Respondents of highway site	35
Table 4.1	Various Percentages of responses for Dam Site	46
Table 4.2	Various Percentages responses for Highway Site	48
Table 4.3	Classification of dam accidents in	50
Table 4.4	Classification of highway accidents	52

List of Symbols

GUI	Graphical User Interface
JUIT	Jaypee University of information technology
Km	kilometers
C&S	civil and structure
BBN	Bayesian belief network
SEM	Systematic structure equation modeling
DfS	design for safety
KAP	knowledge, aptitude and practice
PRA	Priori probalistic risk assessment

CHAPTER 1

INTRODUCTION

1.1 General

In every country construction firm or organization plays an important role not only in GDP of a particular country but also in improving the competitive position of the country. The accidents occurring on construction site not only affect the manpower but also result in increasing the indirect cost including treatment expenses, and also the morale of other workers is affected which result in increasing the actual time for construction. As the construction process is a vast industry the accidents occurring are also larger in number.

Accidents of the workers at the construction site can be marked at the top of the list in regard to other firms than construction. The most critical or occurring accidents are due to falling of a worker from a height. As more work is related at different places so workers keep migrating from one work to another which results in increasing chances for accidents [1]. Accidents in construction process cannot be guessed and they usually affect the planned construction process of the management. Accidents cause large disturbances to working schedules, equipment and workers of a company so it is necessary to find them and recertify the individual one from the root. To avoid accidents as construction site various safety measures can be followed such as safety plans, safety trainings and meetings, proper assessable first aid and medical facilities, proper management roles. There are various types of accidents that can occur on site such as scaffold, trip and fall, crane, ladder, electrical, accidents [2]. To find the most occurring accidents on the site is foundation of construction safety management Proper dealing with hazardous activities is the fundamental to safe construction. Total safety tool has been used in order to rectify hazards more progressively by the engineers. For hazard identification it’s important to cross two steps first knowledge and information step and second is process and procedure step. Both steps have been completed by total safety tool. The accidents which cannot be rectified or are not rectified become the reason for occurrence of accidents. The report of construction firm in terms of safety has always been worst [3].

1.2 Types of Accidents

Accident not just befalls they effectuate due to many incidences or we can say unsafe acts or unsafe conditions. One reason for accidents is also addition of cause to unsafe act or unsafe condition. To reduce the accidents it is important to find the most basic accident. Some of the basic causes for accidents are unsafe method, unsafe equipment, human element, working conditions etc [4]. PRA priori probalistic risk assessment witticisms significant duty to exemplify the reasons of incidents which can lead to accident [5]. The various category of accidents are shown in figure 1.1

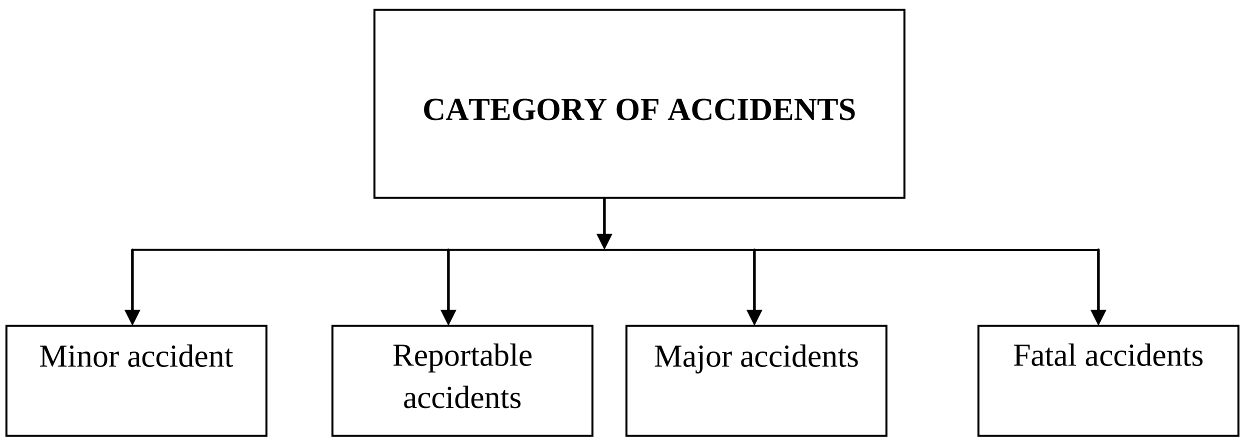


Figure 1.1 Categories of accidents

1) **Minor accidents**

   These accidents are generally near to incidents. It generally includes small accidents which are less harmful to the workers. These accidents prevent employee from working to less than 48 hours. These accidents can be controlled easily and they are not reported to the concerned authority.

2) **Reportable accidents**

   This category of accidents is somewhat greater to the minor accidents. This category prevent employee from working for more than or within 48 hours. The supervisor has the authority to report the higher authority and also appoint another worker.

3) **Major accidents**

It includes the accidents which cause temporary disability or permanent disability of the employee. Major accidents are to be reported at higher level. It prevents the employee from working for 2-3 weeks or even months.

4) **Fatal accidents**

In this category death of employee on worker is included. The compensation is to be provided to the family of the employee and also an FIR is to be lounged in the police station.

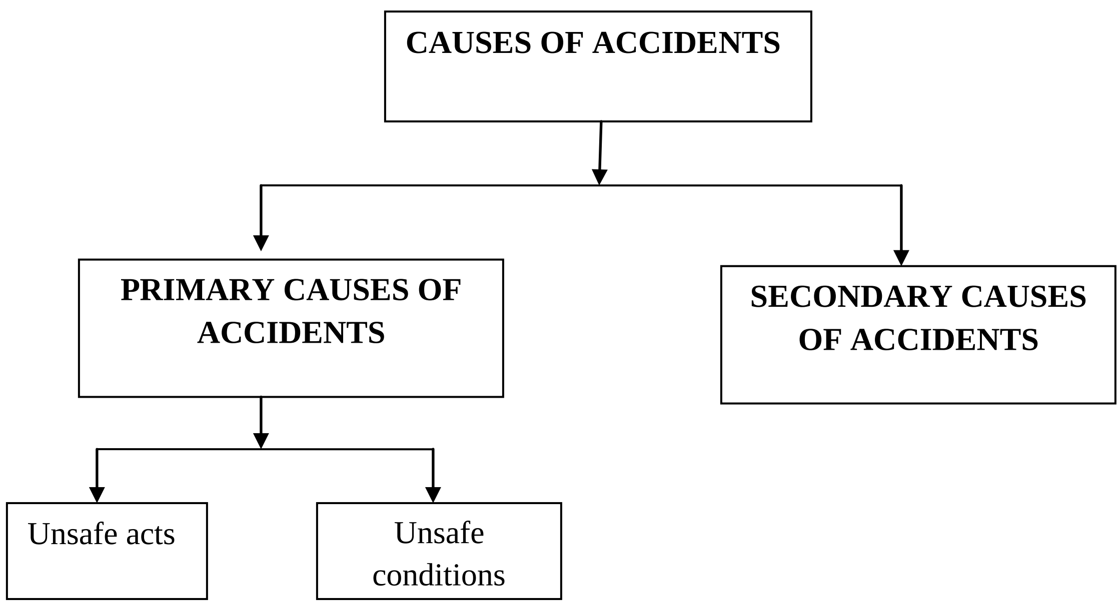


Figure 1.2 Causes of accidents

1.3 Causes of Accidents

The causes of accidents are shown in figure 1.2, an accident can be elaborated as an incident in addition to its consequences, an output of activities or functions that arise due to unwanted consequences for example any injury, damage to the property or machinery, delay of time in construction and also rendering the construction uneconomical. Accident as a whole is dependent on the management or organization as we can say accident is a result of unsafe activities and conditions. It's the duty of management to look after the proper maintenance and strategies required to built a proper safe working environment for it workers.

Causes of accidents are divided into 2 categories:

1) Primary causes
a) Unsafe acts
b) Unsafe conditions
2) Secondary causes

Unsafe acts

The unsafe acts also known as primary acts can be defined as the activity which leads to accidents for example working of workers in absence of concerned authority, no warning signs to be careful, using equipment at wrong speed or in improper way, not following the safety rules set by organization, the loading of vehicles not done in proper way or overloading of the vehicles, no check or maintenance of the machinery at frequent times, working under influence of drugs or alcohol these all factors can be categorized as unsafe acts.

Unsafe conditions

They also come in primary category can be defined as the working conditions which leads to accidents for example no guardrails for the workers, working at heights without any protective or safety measure, improper lightning system, working in very confined place for a long time without any arrangement for proper breathing, leaving the machines in working state without any alarm.

Secondary causes

This section generally include accidents due to management or social pressure for example the early completion of project without any concern about the safety of workers, using bad quality of products to get cost benefits, no appointment of safety manager and no safety drills for workers, improper communication with workers, working of firm in absence of team work, due tradition of working followed in the industry [6].

1.4 Cost of Accidents

Accidents not only have affected the production but also on the cost effectiveness of the project. Cost of accidents can be divided into two parts:

a) Direct cost
b) Indirect cost

Direct cost

It includes the compensation, medical facilities, and legal payments directly by the firm or through the insurance policies followed in the organization. Insurances can be directly related to direct cost. It also includes the medical compensations and property-damage insurances.

Indirect cost

It includes the cost which cannot be accumulated in the insurance. These costs are generally imperceptible but are not less than direct cost. It includes the cost of lost time of worker, cost of time lost by other workers as their morale decreases due to the occurred accident, cost of injured equipments, property, cost of paying wages to the injured laborer in absence, cost of delay of construction.

As, the accidents not only result in minor injuries only but sometimes the accidents can also cause a permanent disability or death of the person so for the safety of the workers and also for a good reputation, good working conditions, economical construction, completion of project on time, and to avoid the indirect cost for example cost for treatment of injured workers, paying compensation to worker etc it is important to rectify the major cause of accident at a starting stage of construction.

Construction industry is liable to more accidents due to the working process and due to more complicated procedure of work. The data collection or statistics are very important to find the source of accidents. Good safety procedure curative action can be adopted an applied to prevent the accidents of same kind. The occurring accidents on construction site are due to fall, errors in machinery and equipments, banging of vehicles, disturbances in vehicles, improper loading and unloading of material onto vehicles, explosion, gaseous fumes and vapors which are hazardous to health of workers, electric shock to workers. It is important to relate the reportable accidents to number of construction project in a particular year this will help in getting the absolute rate of accidents. The incidences, fatal accidents reduced but there was an increase in permanent disability accident [7].

Construction agency is very important pace to be examined a number of workers are involved whose life is important to been taken care of. Construction has many individuals some of them are well educated whereas some may have little skills or no skills at also everyone involved have their lives in risk. It is necessary to accumulate the aspect of safety in order to reduce risks for accidents. There are some main causes for bad safety practices followed in a construction organization such as inabalibility of *PPE* (personnel protective equipment), carelessness of workers in wearing PPE, no safety officer appointed at the site, lack of safety practices at site, no training and drill sessions for the employees by the management, no safety to the workers working at heights etc [8].

There has been no decrease in the top position of construction industry for accidents due to large number of injuries, illness, and fatalities in as in relation to the other industries it is important to have safety check at each and every point of the construction to evaluate the performance of safety for a particular organization. No concern was given about the instinctive and it is possible to get instinctive through quessonnarie or other data collection tools [9].

As the construction firm include consultants, clients, managers, engineers, and communication between all the firms is important to for completion of work. Accidents have a great impact on the on the project by affecting the estimated cost or increasing the time limit [10].Every construction firm is scourged by challenge of accidents which result in impoverished performance. Even many preventive techniques have been applied but with improper approach. A hierarchical risk breakdown structure is used for risk assessment. The fuzzy logic has also been used to identify the sources of risk and their preventive measures in order to not affect the performance of project. But the problem with this research is that it is not accepted by the many business professionals as many alterations have to be done in field of planning as well as in the financial terms [11].

1.5 Data Collection

The quessonnarie form is a good way of data collection of accidents according to the working faculty of the construction site. The main factors were considered in the quessonnarie form for example accidents in absence of higher or concerned authorities, accidents in absence of proper personnel protective equipment, accidents due to using defective equipments or disc cutters, accidents due to improper loading or stacking and poor lifting techniques, accidents due to improper guarding and warning system, accidents due to access scaffolding, accidents due to falling of retaining walls, accidents where workers are under influence of drugs and alcohol, Accidents due to falls, trips and slips of person from height or same level, hitting stationary or moving objects with part of body, accidents due to sound and pressure, body stressing due to muscular stressing while lifting, carrying objects, repetitive moments, low muscle loading, accidents due to contact with heat and electricity, accidents due to environmental factors, accidents due to single or long term contact with chemical and other substances, accidents due to exposure or contact with biological factors.

1.6 Models for Synthesis

SEM (systematic structural equation modeling) this model has been used to assess safety system on construction site. The data was collected in form of quessonnarie form. In SEM model 26 factors were included to check the safety procedure on the construction sites. It also elaborated the reasons that affect the completion of project. They collected the data on three platforms namely:

- State owned enterprise
- Private enterprise
- Sino-foreign joint venture

The indicators that were used to check were safety were safety climate, safety attitude, safety culture, safety behavior. Through data collection of quessonnarie from and relating it with 26 factors it was found that the Sino-foreign joint venture possesses most poor safety performance practices in their enterprise or organization. As collection of data through quessonnarie form is somewhat cost expensive due to large numbers of employees working in construction, a comparison can also be done between firms of two different countries [12]. The accidents not only affect the health of employees but it also affects the property so reducing accidents will also help in saving humans as well the economy. Through surveys and researches in past year the lack of safety and security contribute to occurrences of accidents on construction sites. In past year when incident occur it was investigated and then the remedial measure was found for avoiding accident of same kind in future [13].

As the construction activity is a very strenuous work, where unreliability can pertain at any level. There are various risks involved in any construction project such as financial risk, political risk, legal risk, environmental risk, operating risk, force majeure risk. The collection of data can be done in various ways such as quessonnarie or checklists, interviews, expert system, the delphe technique. The acquirement of any project depends upon how fruitful and productive the measures against misgivings have been executed. It is clear that individual project will have their own problems so the way out for each of them will also be different [14].

Preventive measures taken in safe design, safe can promote early identification of accident during the planning level of a construction project. As hazards or accidents can be know at a very early stage of construction so it is possible to take proper measures to avoid accidents at the later stage of the construction. *DfS* (design for safety) is taken into consideration in many construction projects at Australia, UK and Singapore. DfS generally based on KAP knowledge, attitude and practices. A response of 42 construction and site engineers were taken and interview for them was also conducted to gather the data more briefly. From the quessonnarie collected the main points which were covered are as follows:

- *DfS* was appreciated by many construction and site engineers and they were in favor of involving it in their duty.

- Some construction and site engineers also felt that *DfS* should be a concern of contractor rather being their concern.
- Many construction and site engineers also agreed upon that they have studied about *DfS* in there institutes but the government should provide special training for *DfS* to the employees.
- *DfS* training should not be only started for the professional engineers only but it's important to implement *DfS* at all the levels.

More surveys can be conducted and the samples which are 42 can also be increased. As only construction and safety engineers are involved in the survey clients, laborers, architects can also be involved to do survey on larger basis. As quessonnarie is a laborious process another tools for collection of data can be used [15].

It is necessary for the management to have the some essential skills in order to create a suitable safe working environment and conditions for the entire construction team. Through this research a hypothesized model was developed this model was divided into two parts first step includes laying of safety management task for a better project management whereas in the second level the results were to develop the safe working environment for the whole construction team by the management. The results of quessonnarie were self rated which may cause improbable procedure slant. It is possible for the respondents to have different opinions and understanding regarding safe working environment. The data was done only in three headquarters so more sites can be taken into consideration [16].

We can elaborate risk as anticipated significance related with a given activity. Risk is conjunction of probable event that the particular accident will happen and the callousness of anticipating coming from accident. Other risk calculating tools like probalistic risk analysis tool, fault tree analysis were not able to calculate ambiguity and murky related to the historic data. Therefore in place of traditional tools Fuzzy logic appeared to be more useful in calculation of risk. Fuzzy logic system helps in determining the inconstant accidents.

As with the increase in construction industrialization it becomes important to adopt proper safety measures. Each bode injury depends upon the safety procedure followed in a company or organization. Risk calculation of generally based upon on the previous data collected and experts view therefore the data can be inappropriate or incorrect so it becomes important to consider a range for numeric value that can be used as linguistic variables. Trapezoidal membership function is used as data collected is on larger basis with multiple numeric values. The numeric values were between a and d and most likely between b and c. the data collection helps in good understanding of kind of accidents and details of accidents data collection can be taken from site engineers, safety managers, injured workers [17].

As data collection is important for identification of accidents so it can be managed by quessonnarie form which is filled by the various laborers, engineers, safety mangers, and site engineers present at site. As risk involved for the particular body part has been calculated in the previous research so it is possible to find the most critical accident on the site. The parameters for calculation of accidents is taken as minor, reportable, major, fatal and the maximum accidents are generally of minor, reportable and fatal so triangular membership function or lingitustic term can be used. As in our research values occur between minor and major and most likely to be reportable so it is better to use triangular function than using trapezoidal or other types of membership functions.

As demand for proper safety is increasing at a faster rate in construction industry due to increasing number of accidents which not only affect the health or performance of the employees in construction industry but also result in increasing the actual time of completion of work and also due to delay created by injured work result in increasing the indirect cost of the project and rendering the construction project uneconomical. So it is important to identify the accidents in construction process by making a quessonnarie form including the most occurring accidents on the site. For collection of data quessonnarie method is a good way as it is economical and also allows getting the idea about previous accidents.

After collection of data it is important to group the accidents into four categories that are minor, reportable, major and fatal it can be done manually but it takes more time so grouping can be done using *GUI* and the result can be compared to the manual results. Once categorization is done it becomes easy through fuzzy logic system to find the most critical accident on the site and once it is identification the particular accident can be prevented in future by taking proper remedial measures which will help in increasing the safety of employees and also in reducing the indirect cost and completion of project within the time limit.

1.7 The Organization of Thesis

The first chapter includes the brief introduction to the topic identification and various classes of accidents on construction sites. Various types of cost included in the accidents have also been discussed. A brief illustration of the portion under dissertation is also provided in this chapter.

In second chapter review of literature on identification and analysis of accidents on construction sites through various models and systems that have been conducted in past is elaborated. The objectives of the recent research have also been included in this chapter.

The chapter three includes the illustration of materials and method used for collection of accidental data, step by step discussion of synthesis used for computation and algorithm of fuzzy logic system.

The fourth chapter deals with the results obtained through synthesis of quessonnarie form and fuzzy logic system.

In this chapter the main outcome or judgment which is conclusion has been given which is obtained from results and discussions part of the thesis. Also the future scope which can take place in extension of the same study has also been given.

CHAPTER 2

LITERATURE REVIEW

2.1 General

A Complete review of literature on accidents related to construction sites and their identification through various models and techniques have been discussed in this chapter along with the objectives derived.

2.2 Accidents during Construction

As construction involves many complex works the accidents during construction can take place at any point. 3 accidents at top most are;

1) Due to falls (22.2%)
2) Stepping or waking on objects (18.2%)
3) Struck or bang by falling objects (17.1%)

Another accidents are due to exposure to /or contact with electric current. This type of accident is result of incorrect usage of electric sockets, damaged insulation of electric wires/cables or faulty electric tools. The struggle or tough movement will cause tiredness to the human body and/or unbalance body manoeuvre, caught in between objects, in connection with harmful materials, in connection with extreme temperatures and other type which cannot be taken lightly [4].

It was also found that maximum accidents were due to improper maintenance and improper use of machines or equipments. In figure 2.1 the nine causes for accidents on construction site have been illustrated. An accident due to improper use or maintenance of equipment was found to be the most occurring accident on the sites and followed by falls, being struck, accidents due to collapse of structure, vehicles error, fire, loading and unloading, collapse, flood, explosion, gaseous vapors and fumes, improper storage of material, nervous shocks. These were some of the main causes of accidents which were determined from the statistical and court cases. Identification of the root causes of accidents can help creating awareness about the accidents to the particular organization. In

But the court cases available were limited due to which the research was also confined and it is also important to investigate the statistical data due the modernization of the technologies and methods used for completion of the construction work [7].

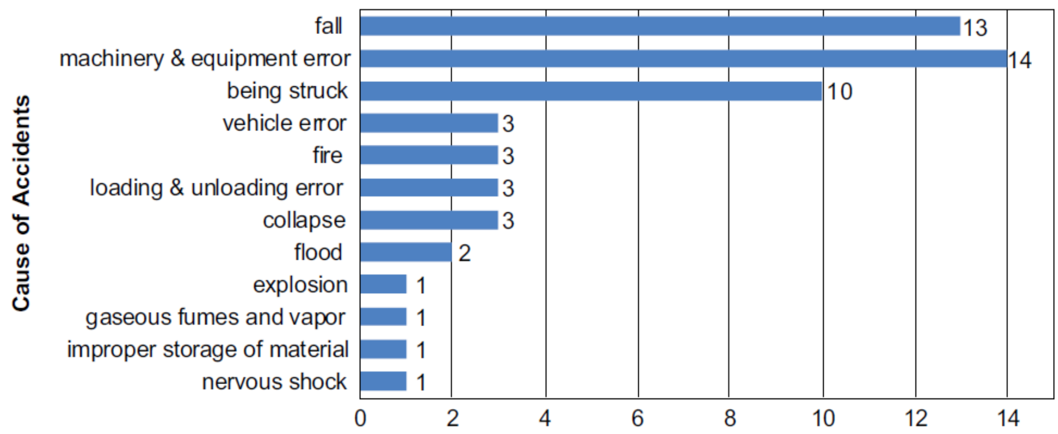


Figure 2.1 Causes of accidents [7]

2.3 Identification Methods for Accidents

For identification of accidents a sample of 450 questionnaire forms from 30 Chinese construction enterprises. Three typical types of construction enterprises namely;

1) State-owned enterprise

2) Private enterprise

3) Sino-foreign joint venture

Were selected to take samples in order to measure the level of safety performance and accidents on construction sites. Quessonnarie forms made it possible to collect data at various levels and large data was gathered. Through quessonnarie form it was possible for all the workers to fill the data individually rather than in a group, quessonnarie form is a laborious process and requires lot of time but provides a great accuracy of the accidents occurring on the construction sites it is possible to collect data in form of group discussion system. Figure 2.2 (a) the age of the responders are shown and it is observed that there are 39 % of respondents whose age lies between 30 to 39 year represents by red color having 41 % of working experience in the construction field, completed their middle class education and a safety training of 1 to 2 year is provided by the company. It was found that self awareness, visioning re some of the skills required to create a safe working environment [12].

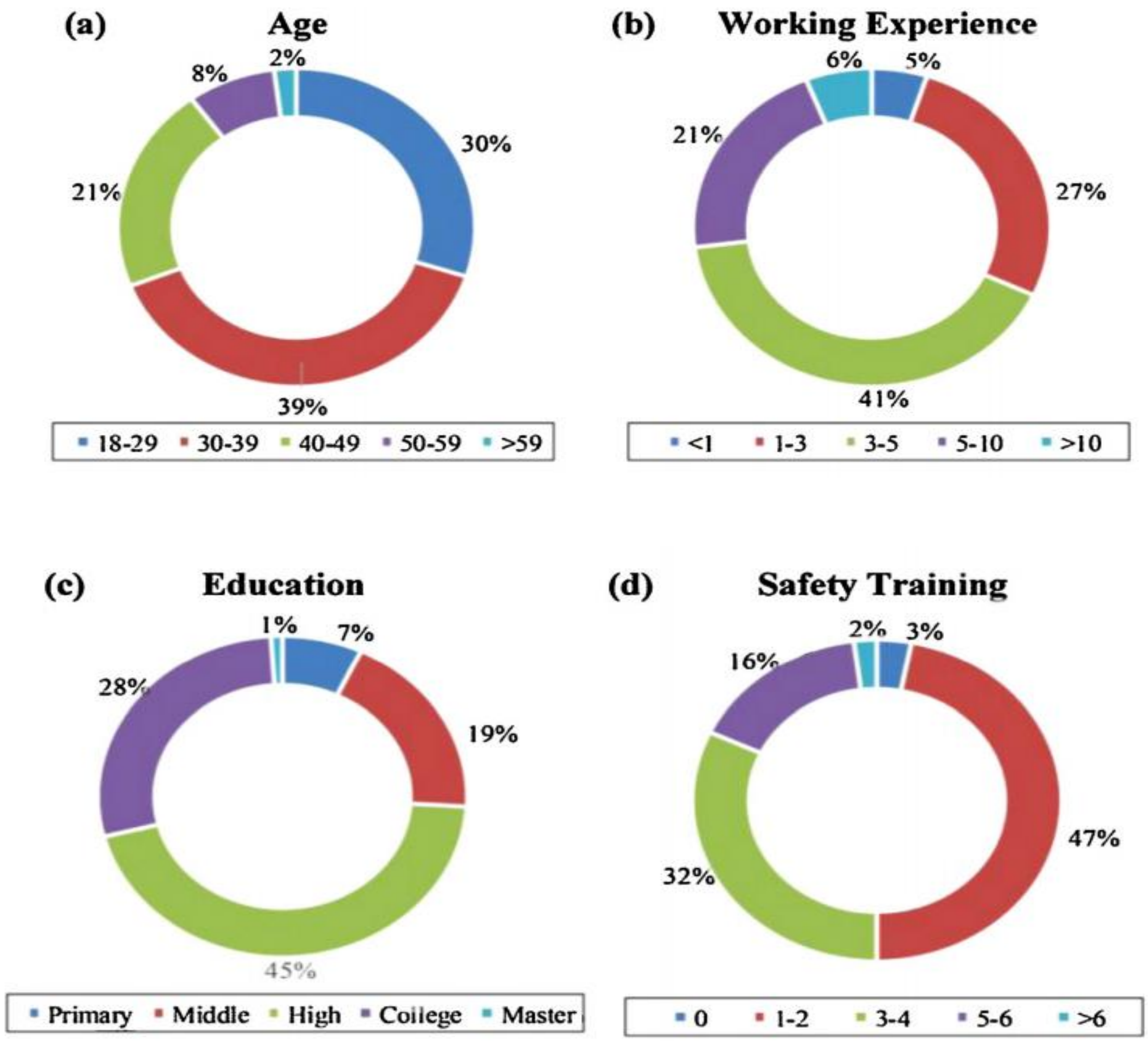


Figure 2.2 (a) Age group of respondents **(b)** Working experience of respondents **(c)** Education of respondents **(d)** Safety training of respondents [12]

Figure 2.2 shows various percentages of the respondents based upon age, working experience, education, safety training. Identified the accidents through collection of two data first is statistical data and data of court cases. In case of statistical data the data on three bases were established as bar graph in respect to accidents on basis of gender, death cases by gender, and permanent cases of disability. Figure 2.3 shows the total number of accidents which have taken place according to the gender. The mean number of accidents for male were 3894 and whereas the mean number of accidents for 384 female [7].

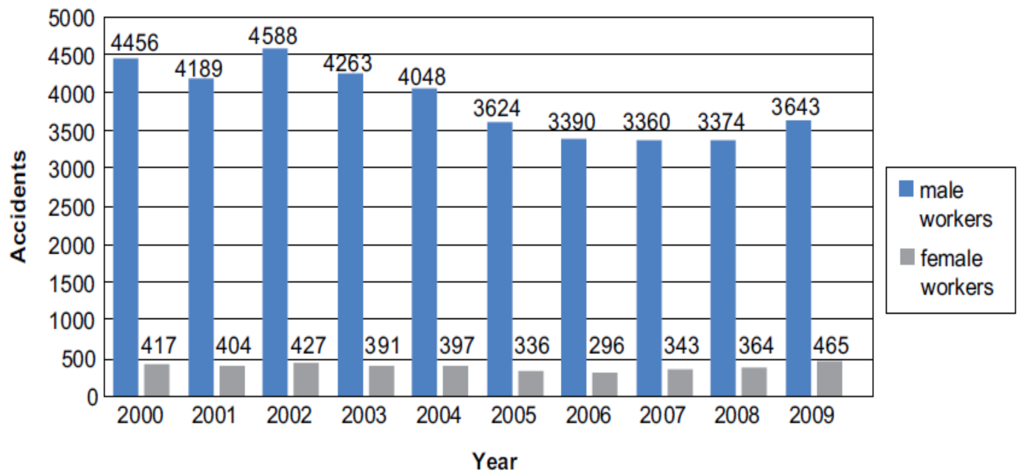


Figure 2.3 Accidents by gender [7]

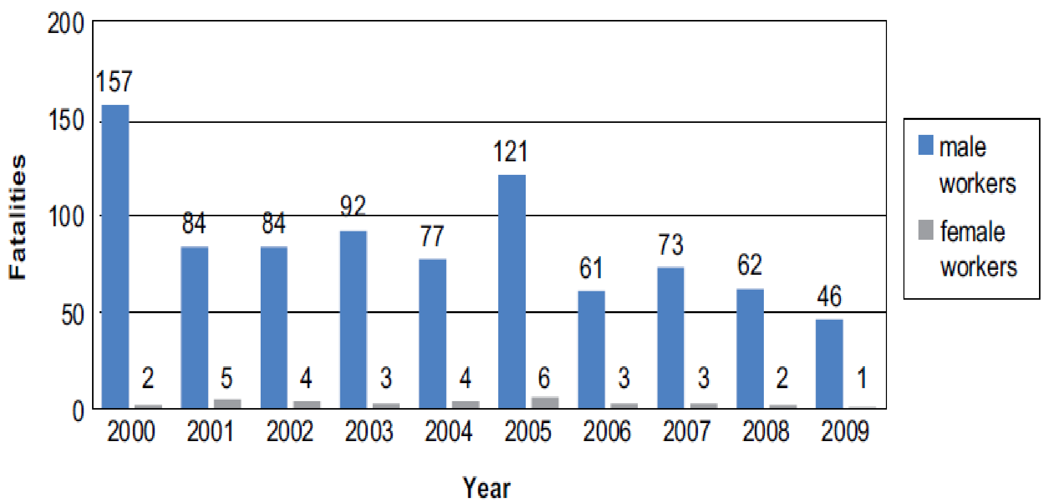


Figure 2.4 Death cases by gender [7]

Figure 2.4 shows the number of death cases based upon the gender. The highest number of death cases was more in males than in cases of females. The death cases were reported to be higher in year 2000 and least death cases in year 2009. Figure 2.5 shows the rate of accidents which causes permanent disability. In year 2009 the maximum cases of accidents causing permanent disability was found to be higher in case of male workers. The accidental data from 30 court cases was also used for identification of accidents and most of the cases were civil suits [7].

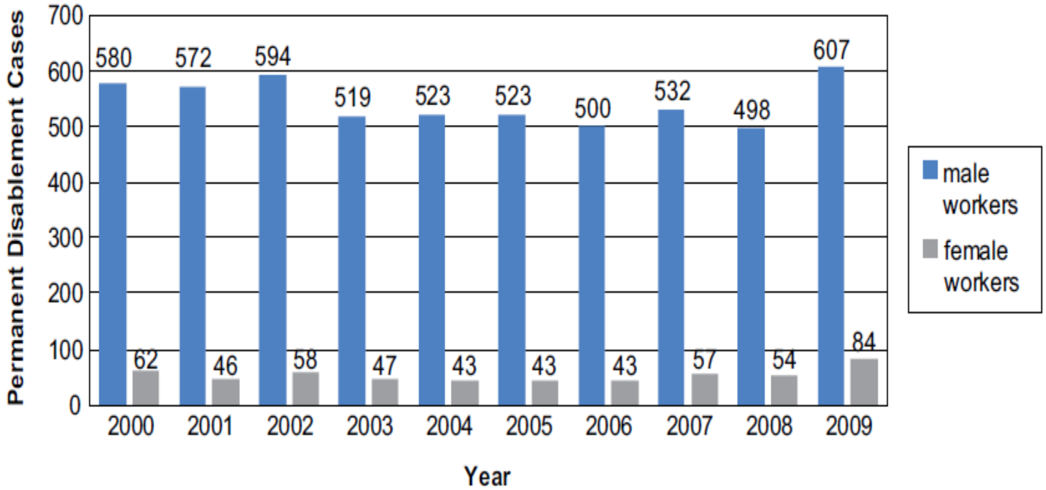


Figure 2.5 Permanent disability cases by gender [7]

The main concern was to quiz the construction site and find the reasons and effects of accidents. To discuss the relationship of accidents in respect to project cost, project time, company reputation. The collection of data was completed by an online source and some data was also collected through case studies. In this research it was found that the main cause for accidents in construction is due to negligence of the workers. The improper training and the improper knowledge about the working of appliances also lead to increase in number of accidents [20].

Reviewed the importance to check or maintain the relation between management and safety and for this purpose 16 construction sites were taken into consideration a checklist based upon safety was made to be measure the recent safety proposal followed on the site. The checklist included the basic reasons which could directly or indirectly lead to the occurrences of accidents on various construction sites. The checklist included only the limited factors with no provision for addition. Through the research it was concluded that the supervisors mainly focus upon the completion and proper execution of the work instead of paying attention upon the safety sets or rules to be prepared for workers. Many accidents were also as a result of not focusing on to the health and safety regards of the workers at the construction site. The results mainly focused upon the communication of supervisors with the workers [19].

2.4 Synthesis of Data

For synthesis of data presented a *SEM* (Systematic structure equation modelling) method for evaluating PSPE (Prospective Safety Performance Evaluation) on construction projects. The data is collected by interacting the workers or the employees on the construction sites. As per the sample of 450 valid questionnaire surveys taken from 30 number of Chinese construction enterprises, '*SEM*' model along with 26 objects integrated for PSPE in the context of Chinese construction projects has been recognized and then established through test [12].

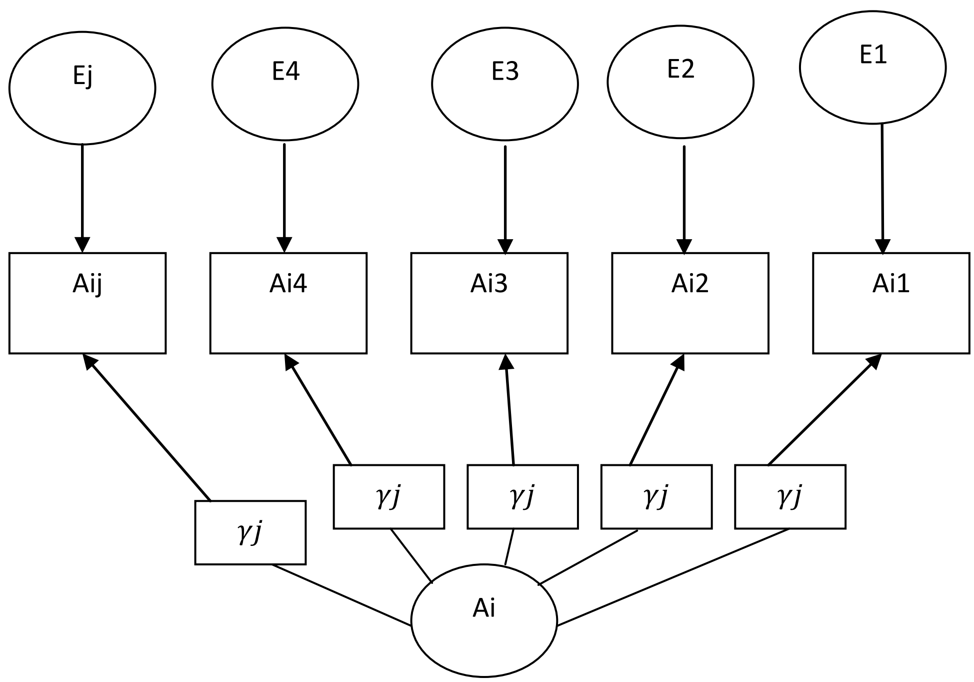


Figure 2.6 Simplified measurement model [12]

Normally the, *SEM* consist two kind of model namely measurement and structural model. The simplified model is shown in Figure 2.6 it describes the ability of variables to compute the latent parameter addressing the reliability along with validity. Figure 2.7 shows the structure model which describes the relationship among the latent factor by knowing the quantity of explained and unexplained variance. It is generally based upon fact that safety performance depends upon four factors safety climate, safety culture, safety attitude, safety behavior.

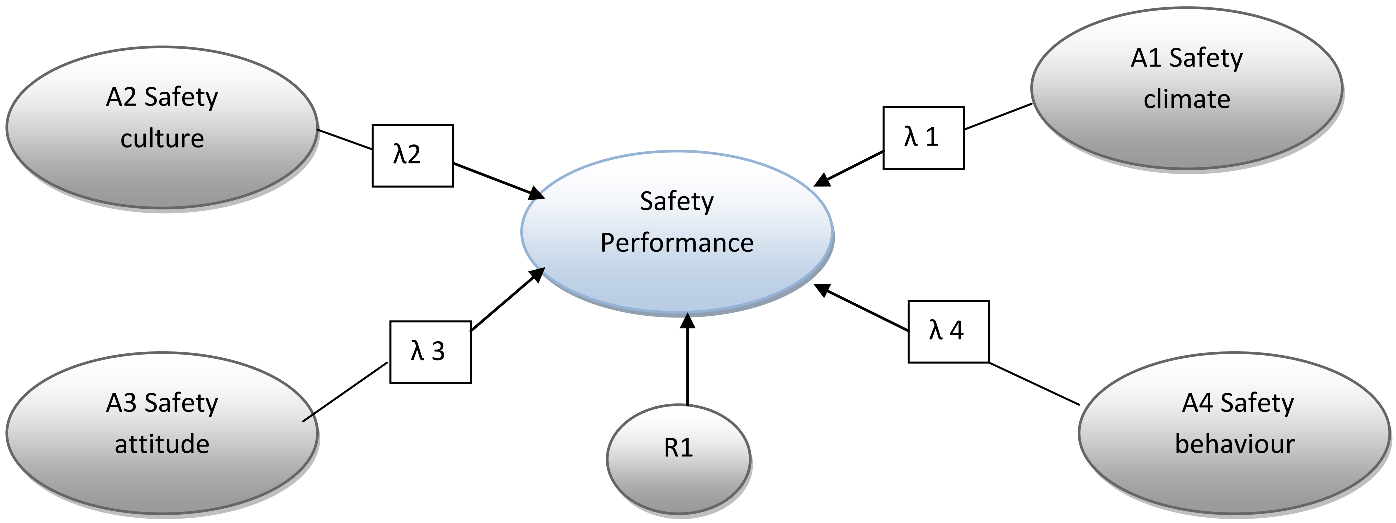


Figure 2.7 Simplified structure model [12]

They developed a model based upon hypothetical abilities. Figure 2.8 shows the various researches required for safe working environment. It has been found that for safe working environment many factors need to be considered such as economic analysis, human aspect, and safety risks, safety in design and procurement, training and learning and these are further divide into various classes such as economic analysis is based upon optimisation, cost benefit, productivity. Human aspect is dependent on stake holder, legal, policy, regulatory, safety culture psychology.

Training and learning is dependent on e-learning, pedagogy, indicators benchmarking, risk mitigation and emergency responses. Safety risk is dependent on risk identification and assessment, risk reduction, automation. Safety in design and procurement was dependent on many factors namely robotics, methodology, business model, legal aspect, sustainability. It was found that self awareness, visioning re some of the skills required to create a safe working environment. It also suggested that proper training of workers and proper safety management can help in creating safe working environment. Various construction sites were assessed on the five factors and the measures were adopted based upon their factors on which they are dependant. Normally, the respondents are very well-known with the construction engineering training that improved the quality of the 'questionnaire data' and the expressiveness of the analysis results.

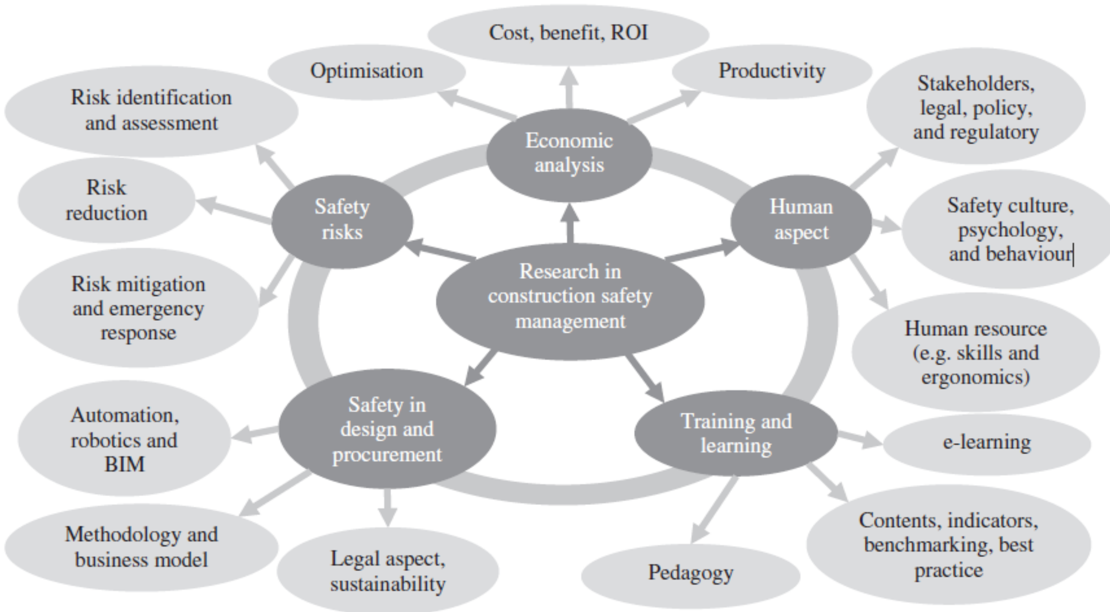


Figure 2.8 Framework of research in construction safety risk[12]

Another method was safety design, *KAP* of civil and structure in order to know the improvement for the further research. The authors analyzed that there is a lack of '*KAP*' in the management of construction and also helps to give the necessary information for the future utilization of *KAP* architecture. The responses of the quessonnarie form were collected from various *C & S* (civil and structure) engineers.

For analyzing the quality level a questionnaire have been prepared, which is responded by the 43 number of *C & S* (civil and structure) engineers. To know the effectiveness of the DFS model it s necessary to study the contractual arrangements. Figure 2.9 represents the five numbers of factors that affects the rate of DFS namely designer mind set towards safety, legislative forces in promoting design for safety example policies, regulations, designer have necessary support from the industry, organizations, stakeholders, DfS tools and guidelines are readily available for use and references, engaging experts who are knowledgeable, about design for safety modifications to guide designers. From the graph it is clear that the engineers those have the knowledge about the design and safety are required for the construction of the project. It is capable of determining direct and indirect relation between the accidents [15].

Figure 2.9 DfS factors [15]

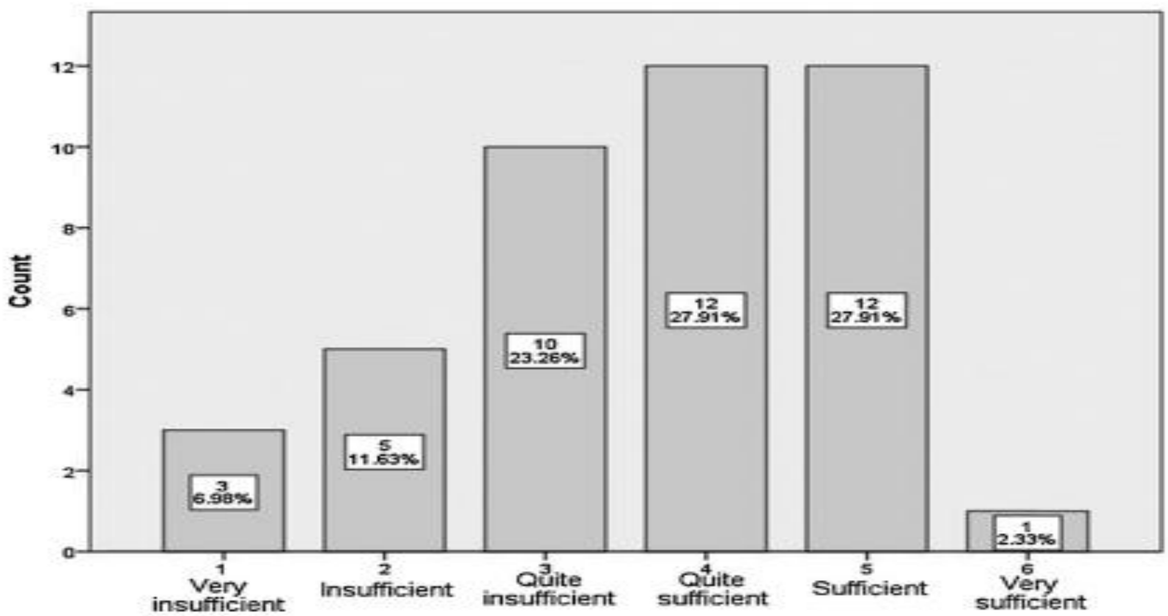


Figure 2.10 Adequacy of accessible DfS guidelines and materials [15]

Figure 2.10 shows the probability of *DfS* being used during the construction. From the figure it is clear that *DfS* used 30% approximately (Sometimes), 38 % (rarely), 18.60 % (never), 10 % (often) and 7 % (always). This chart also indicates a current lack of *DfS* guidance material. It is important to develop tools and guidance material in order to enhance the *DfS* knowledge of engineers. Also it has been noticed that there are existing efforts in developing local guidance material for *DfS.*

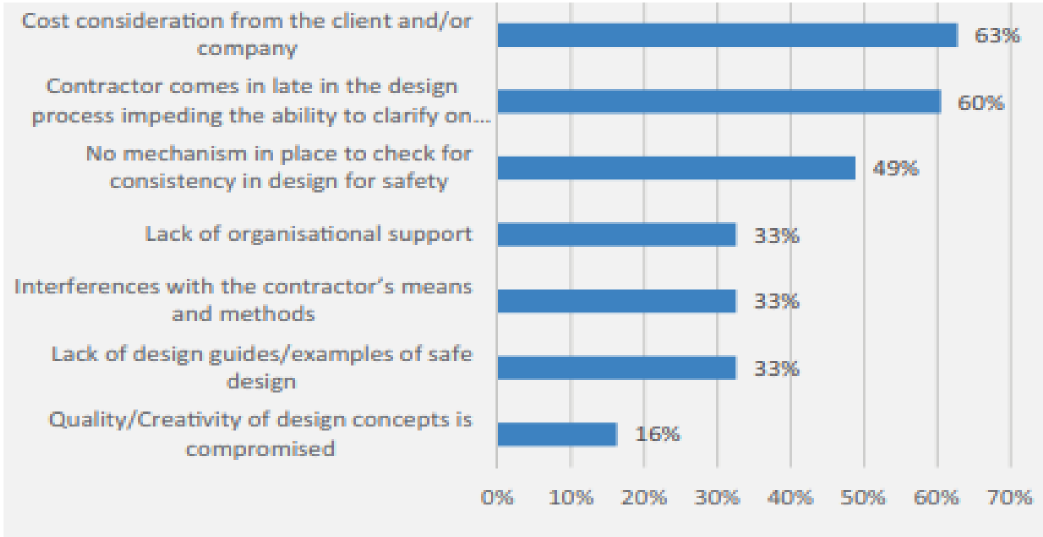


Figure 2.11 DfS Issues faces in practice [15]

Figure 2.11 represents the issues faces by the *C & S* engineers. As per the respondents it has been observed that when DFS is in used the cost consideration is 63 %, Lack of before time participation of the contractor is 60% and lack of method to verify for constancy in DfS is 49%. Thus, to study the above mentioned problem becomes necessary in order to resolve the problem [15].

A safety framework has been developed knowing that construction industry is one of the most dangerous industry. The research also included a case study on which the research was applied to validate the results. It includes various types of methods in the model for identification purpose.The safety framework included the factors based upon the experience and the past research. As an output of case study it was found that the accidents have been decreased to a greater level by imposing of the safety framework. The safety performance on any construction site can be calculated by taking into consideration and calculation of three factors:

a) Safe behaviour and condition

$$\%\ \text{of P (Safe behaviour and condition)} = \frac{\text{No. of safe behaviour conditions}}{\text{No. of observations}} \quad (1)$$

b) Unsafe behavior

$$\% \text{ of P (Unsafe behaviour)} = \frac{\text{No. of unsafe behaviour}}{\text{Total no. of observations}} \quad (2)$$

c) Unsafe conditions

$$\% \text{ of P (Unsafe conditions)} = \frac{\text{No. of unsafe conditions}}{\text{Total no. of observations}} \quad (3)$$

Using equation (1), (2), and (3) a model was developed to check safety performance on the construction sites using safety framework. To check the probability of the safety framework a site was selected in order to make the site evaluation for safety purpose [9].

A proposed quantitative confidence techniques need further justification before the recommendation as per the basis for choosing whether the assured argument justifies fielding a critical system. The burden of proving that a guarantee argument self-confidence quantification method produces reliable assessments lies with its proposers. Several issues related to proposals were the unavailability of trustworthy source data, scalability, unspecified decision procedures, improper treatment of context, out of context statement.

The techniques which were already proposed were considered in this research. There were 12 number of chosen proposal that have been qualified for the assurance cases. Safety can be directly related to two factors namely occurrence frequency, severity of failures. First and foremost the hazard were identified than the hazard were eliminated by a proper argument over various hazards by divided them into various categories. Out of 12 methods it has been recognized that there are five number of proposals that depends upon the *BBN* (Bayesian belief network), six are depends upon dempster shafer theory and one is used for weighted average. In case of *BBN*, the analyser's create a network that consist nodes with the help of *BBN* tool. This reduced the burden on the engineers as well as the safety managers. The non leafed nodes are being compute by *BBN*, also taking into consideration claim of safety interest. Every node defined a variable and when no arrow is presented indicated the independent Figure 2.11 Josang's opinion triangle help in determining the belief, disbelief, and uncertainty of the accidents which cannot be controlled by adopting measures [18].

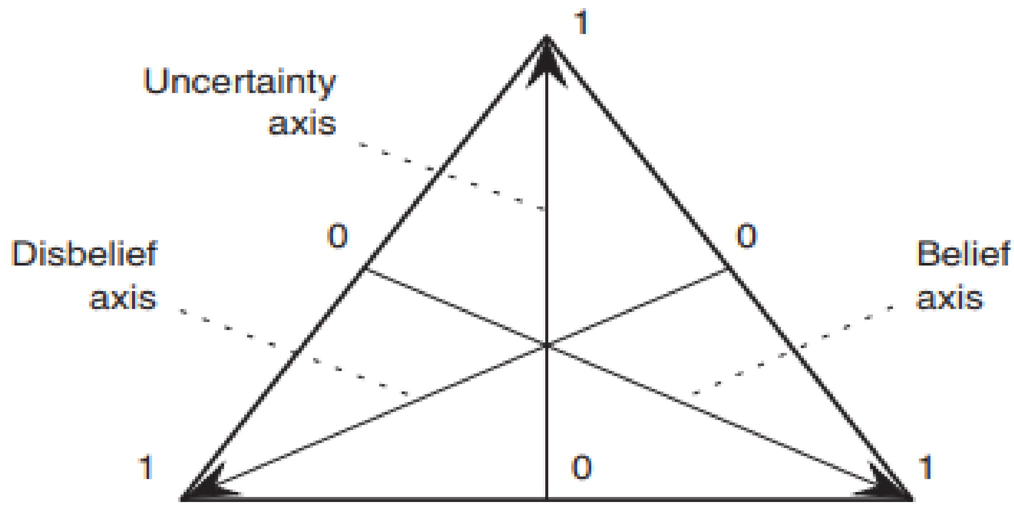


Figure 2.12 Josang's opinion triangle Graydon et al. [18]

It is also important to find the incidents or the near misses in order to prevent the occurrence of accident in future. This research deals with the relationship between the human errors as well as the errors due to machinery or equipments. The main collection of near misses was only given the prime importance in this research. Quantitative evaluations of combined incident reports can help construction firms by generating their overall safety level as expressed by the reports.

This system can also used as a tool for assessing not only the construction company but also each individual section (such as a regional unit) within the firm in purpose to promote a competitive system for evaluating safety-related achievements. Total solution is determined by individually addressing each section of the query, as demonstrated by the decision matrices at the different structure levels of the hierarchy. Other organizations, such as authority institutions, can also gain insights related to the firm safety, provided they have exposure to safety incidents as required [21].

Figure 2.13 shows the hierarchical structure of outcome severity level grading. Main aim was to determine the potential for total damages to the construction company due to accidents on construction site (AHP Level 1). Level 2 includes the two damage aspects overall monetary damages and company reputation damages. And Level 3 included the four accident outcome severity level definitions, for each of the two damage aspects.

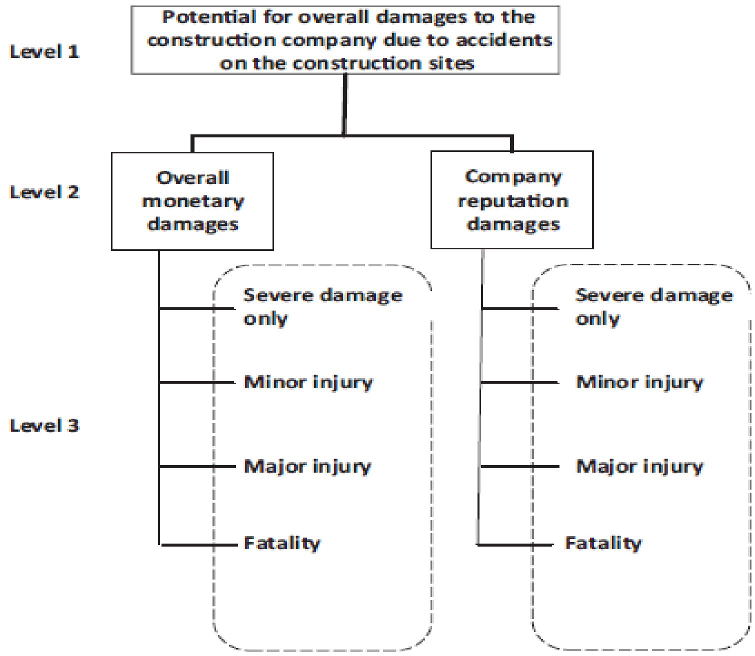


Figure 2.13 Hierarchical structure of outcome severity level grading [21]

2.5 Fuzzy logic

Investigated a probabilistic assessment approach for protection risk investigation for metro construction in difficult project. A confidence index for the estimation of basic events in order to ensure the flexibility of the gathered data during the investigation of experts. Also the defuzzification method has been designed which is depends upon the representation theorem that overcome the disadvantages of fuzzy linear approximation. Due to lack of adequate data it is quite difficult to identify the probability of the accidents. It may be possible to have a sufficient data but the risk involved is higher in coal mines, nuclear power plants. To determine the factors that are responsible for the top event failure have been evaluated by using the importance index and calculating the fuzzy importance. For decision analysis a step by step procedure have followed;

1) Firstly the identification of the hazards or problem is done, than possible risks are calculated further they are divided as top events and sub events.
2) Secondly plotting of top event is done, failure points are determined and by taking the idea from basic events the fault tree is constructed.

3) A skilful investigation is than carried out to detect the possible probability of events, gathering data, the conversion of linguistic and fuzzy utterance into fuzzy numerals after this the calculation of fuzzy probability based upon the basic events is done.
4) Defuzzification is done after the fuzzification of the data takes places, it calculates the failures involved in the fuzzy probability, converts the fuzzy probability into crisp value and then calculation of results is done.
5) In last the most critical sensitivity factor is being determined which are related to the risk analysis output, and adequate control, measures are proposed against hazards and resolving the monitoring reviewing of the process is done.

Figure 2.14 and figure 2.15 represents the relationship among the events OR & AND gates one is input and another is output. First one is dependent whereas the second one is interdependent [5].

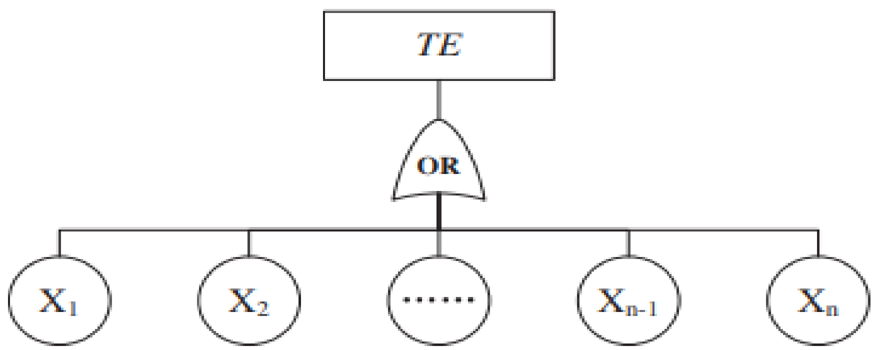


Figure 2.14 Representation of OR gate [5]

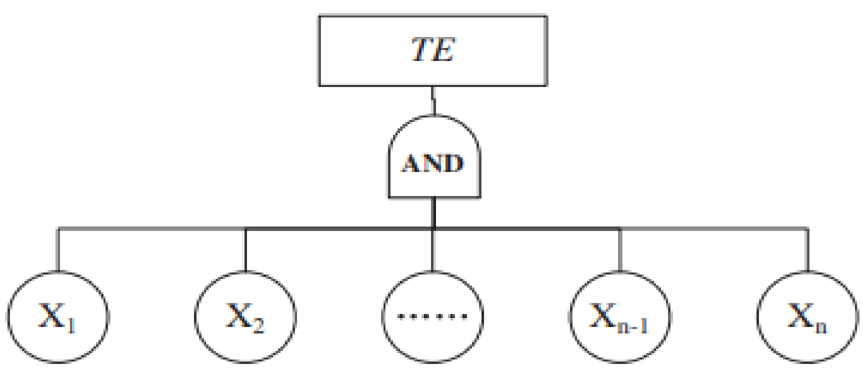


Figure 2.15 Representation of AND gate [5]

Figure 2.16 shows the four steps included in the fuzzy logic system which include risk recognition in order to detect the possibilities or misses. Owing to the high potential risks for the metro construction in complex environments, the fuzzy probability analysis should meet the highly required precision for the purpose of safety management in the metro construction practice. However, the precision of the calculated results is significantly affected due to the limitations in current approaches for fuzzification and defuzzification.

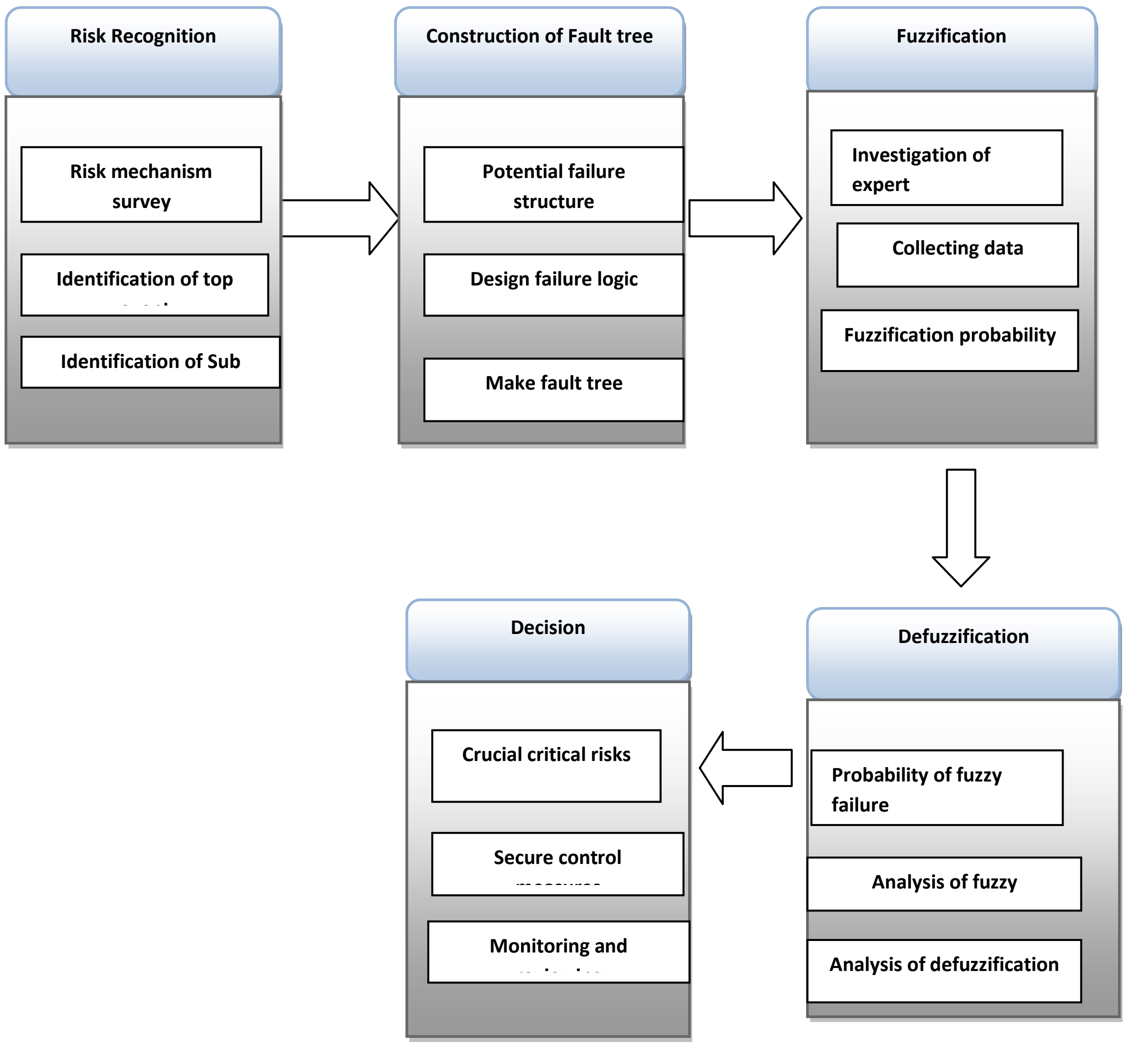


Figure 2.16 Steps included in fuzzy logic system [5]

Examined the consideration of all the body injuries internal or external. The risk with respect to particular body injury has been calculated using fuzzy logical reasoning system and fuzzy analytic process. The risk has been calculated for overall inspected sites.

This research is beneficial in getting both quality and quantity benefits by determining actual and probabilistic risk of injuries. These researches have been proved beneficial to the safety managers in achieving more safety and better productivity of the workers at the construction site. In this research a case study has been done which shows the various types of body injuries that occurred on the site to workers for last 10 years. AP, AS, ES are taken as input and RS is the result of input. [17].

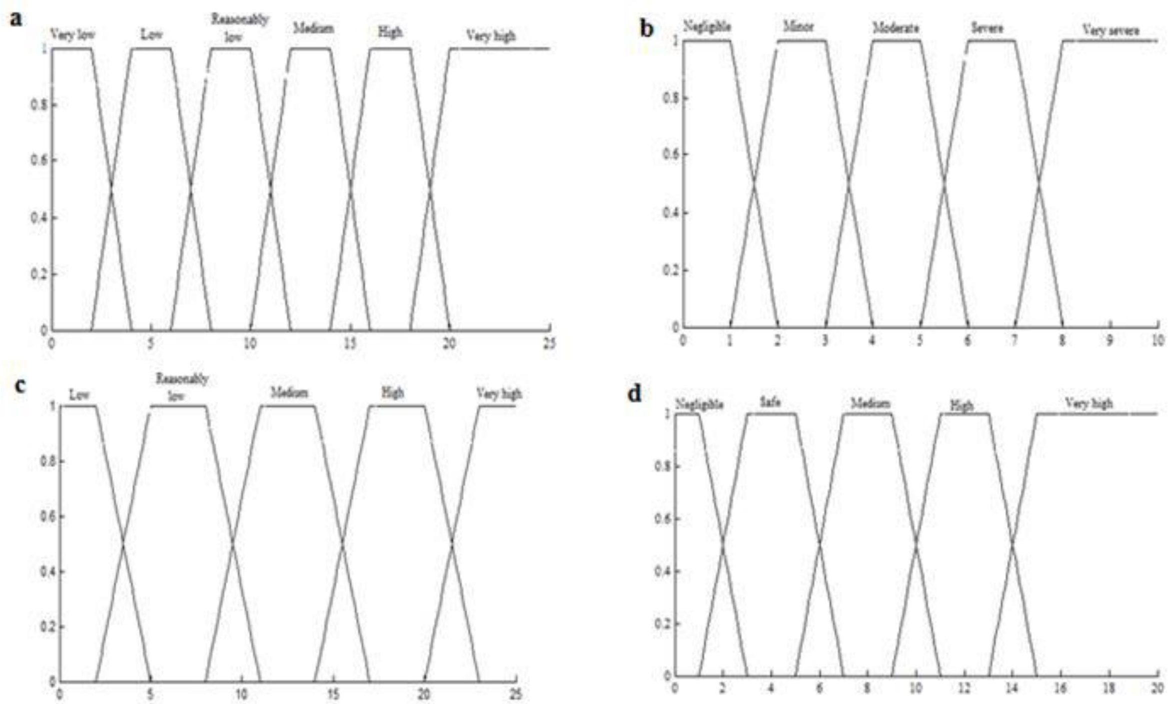


Figure 2.17 Linguistic variables [17]

Investigated the grading of risk meltdown has been established to find the risk assessment. A bond amongst risk factor, risk are considered and checked. Fig 2.17 it shows the membership function which is used in fuzzy logic system to determine and to establish the relation between fuzzified and fusilier. Fuzzy set hypo synthesis is launched to sanction combined risk evaluation descriptions to be modeled mathematically. Risk is identified in terms of time, cost, quality and safety changes. Figure 2.18 represents the triangular membership function from low, low to medium, medium, medium to high and high. As the points to be involved for fuzzy logic were mainly dependent on three factors so triangular membership function was recommended [11].

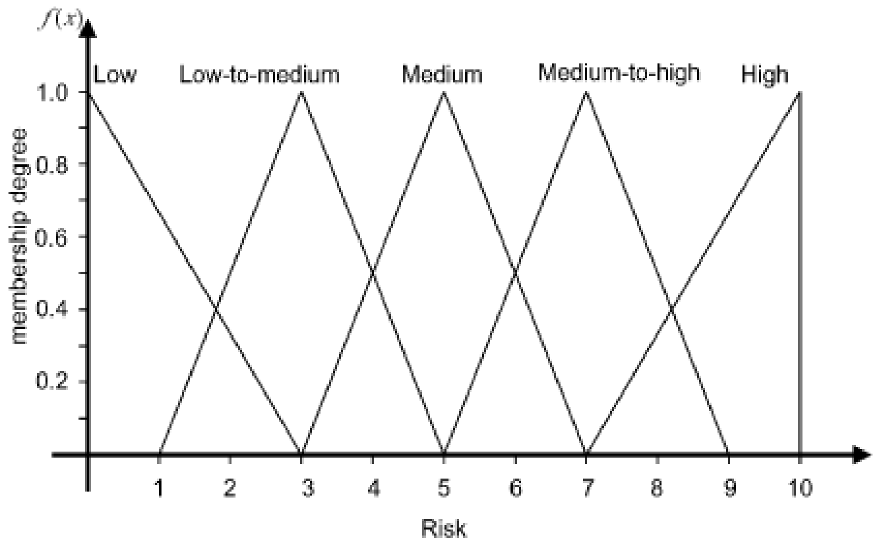


Figure 2.18 Membership functions for risk Carr et al. [11]

As shown in figure 2.18 the triangular membership function from low, low to medium, medium, medium to high and high. As the points to be involved for fuzzy logic were mainly dependent on three factors so triangular membership function was recommended. Figure 2.19 shows the server architecture that indicates the data which is perfectly detached from the user. The freedom empowers replacement to be made in particular modules with negligible or very less influence on others. This research has included for the prototype model and improvement of the risk assessment.

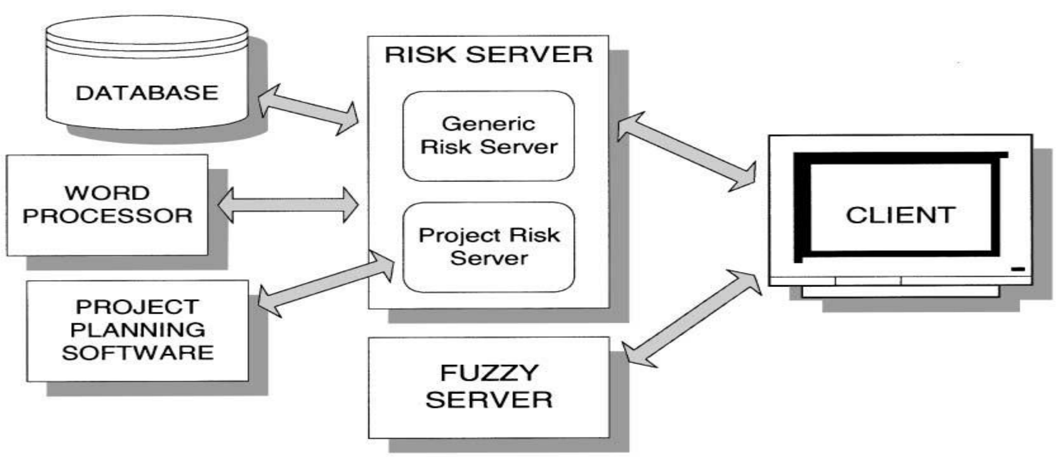


Figure 2.19 Sever architecture for risk system [17]

Studied the importance of potential hazard and potential planning for reducing the occurrences of accidents on construction sites. The data gathering have been done from previous research, advice of experts and various studies. As a resultant the fuzzy logic was used to reduce accidents. Fuzzy logic help in determining the probability of accidents which can or may occur in the future whereas the previous model discovered were only capable of finding the accidents that have been occurred in the past and than finding the solution for only those accidents.

Figure 2.20 shows the overall framework of the research in form of flow chart. The data collection was done and data received was for analyzed for hazard identification. The results obtained were then applied fuzzification, inference and defuzzification in order to determine hazard level. As it is known as construction causes a huge movability so it is important to check the construction process at each level. Fuzzy logic system is one of the best techniques to keep a check the safety at various platforms. It can be found that maximum accidents occur due to fall off workers from a height [1].

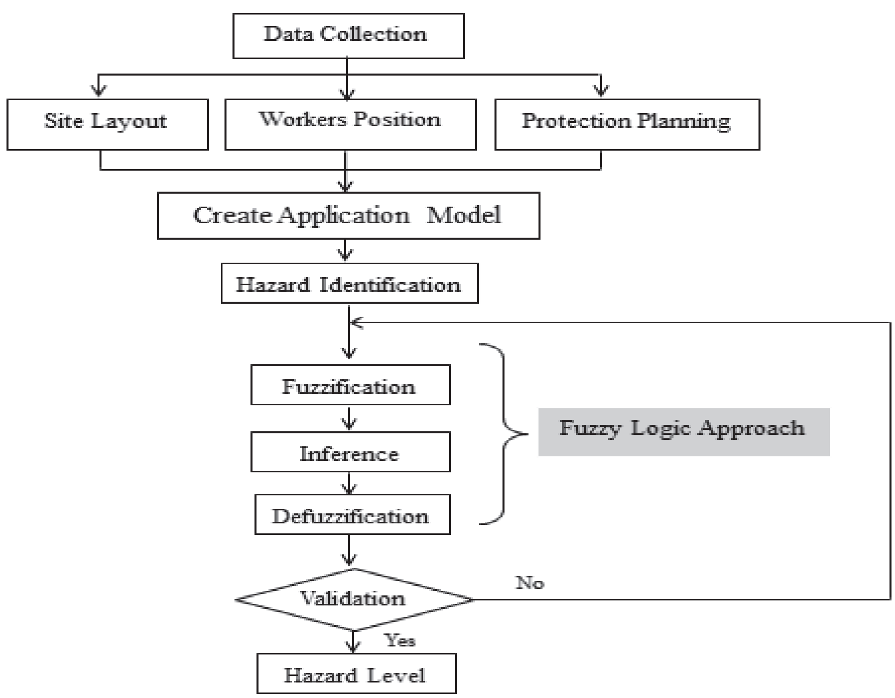


Figure 2.20 Analysis framework [1]

2.6 Summary of literature review

Safety plays an important role in any type of construction industry in terms of workers safety, cost, and completion of work in the scheduled time period. A vast study has been carried out in the field of accidents on construction industry, it was found important to rectify the root causes for accidents.*SEM* (systematic based approach) was used to built the connection and dealing between enablers and purposes of construction which specified the importance of accidents at construction sites.KAP (knowledge, aptitude and practice) was simple and flexible framework designed that provided a useful approach for understanding the importance of failure of construction projects in absence of safety assurance. A greater inter-dependence of PESE (prospective safety performance evaluation) was examined along with identification and remediation of accidents, which in turn, facilitates performance improvement in the construction industry. But still these models lack in finding the probability of the accidents which may occur on any construction site later on this was made possible through fuzzy logic system. Based on the literature review following objectives have been derived;

Objectives

1) To identify the accidents in NTPC Koldam and kiratpur- Nerchowk highway construction using questionnaire method.
2) To determine the most critical factor for accidents at both sites using fuzzy logic system.
3) To carry out comparative study of critical factors at NTPC Koldam and Kiratpur-Nerchowk highway.

CHAPTER 3

METHODOLOGY

3.1 General

The method used for collection of accidental data on dam and highway site is elaborated in this chapter. This chapter also includes the synthesis through graphic user interface and fuzzy logic used in identification of most critical accident on dam and highway construction.

3.2 Steps in Methodology

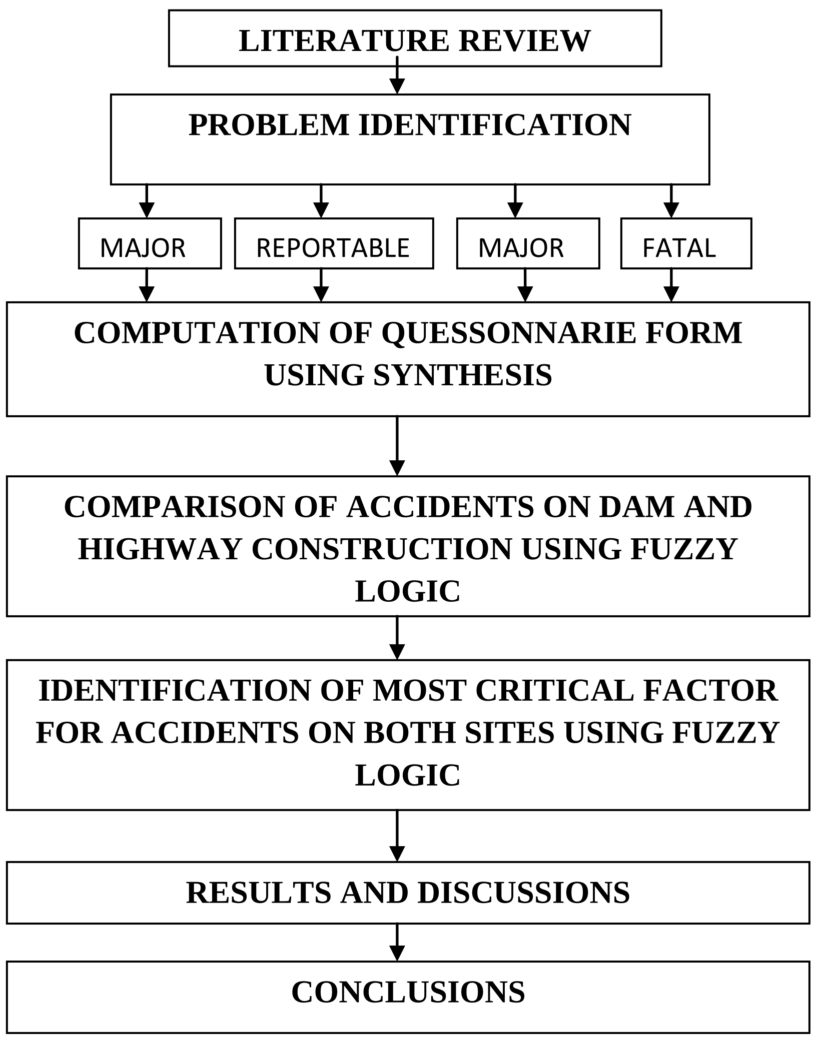


Figure 3.1 Work plan of methodology

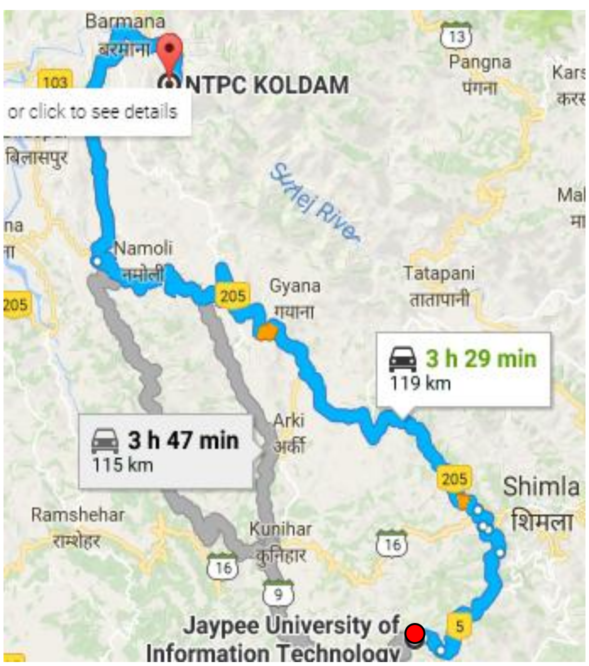
As shown in figure 3.1 a step by step procedure was followed in methodology in which first step was to get a review of research which has already been performed in the field of accidents on construction sites. After going through literature review the accidents on dam and highway sites were identified using quessonnarie method. Data received from quessonnarie forms was than computed by using graphic user interface in order to classify the accidents as minor, reportable, major, and fatal. Fuzzy logic was than applied on the classified accidents for comparison of sites and to find the most critical accident on both the sites. At last the results obtained were discussed and conclusion was derived.

3.3 Material

As literature review has been discussed before in the previous section. For finding the accidental details two sites have been taken into considerations which are as follows:

- Dam construction (NTPC KOLDAM)
- Highway construction (KIRTPUR-NERCHOWK 18.88Kms stretch)

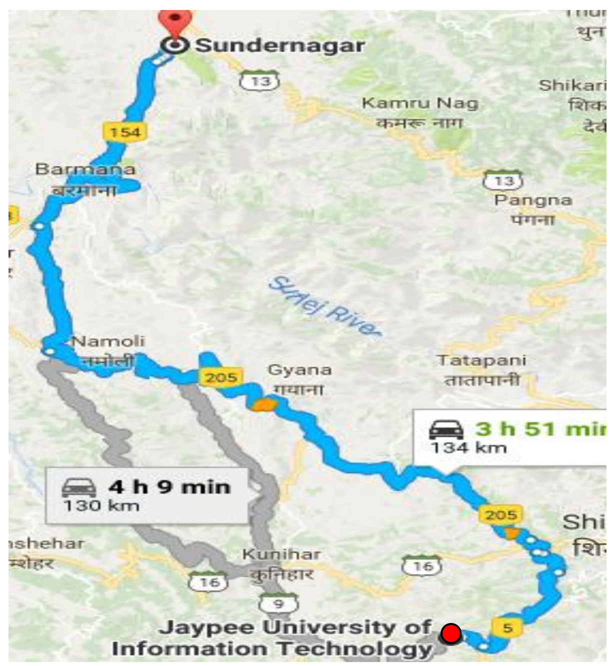
LATITUDE 31.385528° LONGITUDE 76.893127°



LATITUDE 31.021826° LONGITUDE 77.068898

Figure 3.2(a) JUIT to dam site route[24]

LATITUDE 31.535260° LONGITUDE 76.881480°



LATITUDE 31.021826° LONGITUDE 77.068898°

Figure 3.2 (b) JUIT to highway site route[25]

As shown in figure 3.2 (a) the dam is located at a distance of 119kms from *JUIT*(jaypee university of informationand technology) and figure 3.2 (b) shows that the highway site is located at a distance of 134kms from *JUIT* (jaypee university of information and technology).

3.3.1 Dam construction (NTPC KOLDAM)

The NTPC (National thermal power cooperation) project is generally known as Koldam which is situated on the Satluj River. It is situated in Barmana, district Bilaspur, Himachal Pradesh. The major goal of Koldam is to generate hydroelectric power of 800 MW and was constructed by the National thermal power cooperation. It is an embankment dam, it is at an distance of 18kms from district bilaspur off to Chandigarh Manali highway, from Chandigarh the NTPC koldam is situated at an distance of 160.2 kms, from delhi the distance to the NTPC koldam site is 393.9 kms. Due to construction of this dam in Himachal a great platform was opened for the people searching for job and it also helped in increasing the tourism.

As shown in table 3.1 the questionnaire form filled at the Dam site were 50 in number which includes 8 samples filled by engineer, 8 samples filled by the site engineer, 8 samples filled by the safety manager, medium used for all three was English [Appendix A1]**.** Whereas 26 samples were filled by laborers for them medium of language was Hindi [Appendix A2]. The answers filled in quessonnarie form were based upon particular individuals perspective about the accidents which took place in past Total samples filled at dam site are 50.The questions included in the quessonnarie form are based upon the most the most occurring accidents that are assumed to be occurring at any construction site.

Table 3.1 Respondents of dam site

Medium of quessonnaire form	Designation	Number of samples
English	Engineer	8
English	Site engineer	8
English	Safety manager	8
Hindi	Labour	26
		TOTAL 50

Figure3.3 (a) Workers working a height[26] **Figure3.3 (b)** Striking of worker with vehicle

Figure 3.3 (a) and figure 3.3 (b) shows the pictures of workers working at a height without belts for safety purpose which may result in an accident and second picture shows the a construction site where no provision for danger signs are available which can also result in an accident.

3.3.2 Highway construction (KIRATPUR-NERCHOWK 18.88 kms stretch)

The Kiratpur-Nerchowk is a four-lane project, executed by India's NH AI "National Highway Authority", which is two years behind schedule, costs Rs. 188.447 billion and is expected to be operational by December 2018. The general manager of NHAI Himachal in H.P namely Retd Col. Ram Swaroop Puri said that about 67% of the project was completed and it was added that the construction of the two bridges remains a daunting task, as the 40-metre deep working time is only 3 months (March to June) and the foundation needs to be excavated. The project will reduce the distance from Kiratpur to Nerchowk from 130 km to about 84.38 km, of which 50 km is a green route, which means that the road will pass through the 50-kilometre virgin road for the first time. The project will build five tunnels with a total length of approximately 5,070 meters.

Table 3.2 shows details about the questionnaire form filled at the highway site which includes 8 samples filled by engineer, 8 samples filled by the site engineer, 8 samples filled by the safety manager, medium used for all three was English [Appendix A1]. Whereas 26 samples were filled by laborers for them medium of language was Hindi [Appendix A2]   . Total samples filled at dam site are 50.

Table 3.2 Respondents of highway site

Medium of quessonnaire form	Designation	Number of samples
English	Engineer	8
English	Site engineer	8
English	Safety manager	8
Hindi	Labour	26
		TOTAL 50

Figure 3.4 (a), (b), (c) and (d) shows the pictures of soil stabilization, tunneling process, retaining wall, tunnel construction these places are the most liable places where most of the accidents took place during the construction of kiratpur-nerchowk highway.

Figure 3.4 (a) Soil stabilization

Figure 3.4 (b) Tunneling process

Figure 3.4 (c) Retaining wall

Figure 3.4 (d) Tunnel construction

3.4 Data Analysis Methods

Two methods were used in order to accomplish the desired objectives which were synthesis of data through *GUI* to classify the accidents and fuzzy logic in order to find the most critical accident and for comparative analysis.

3.4.1 Implementation of synthesis

Once the quessonnarie form were filled at both highway and construction site it was important to classify the accidents into minor accidents, major accidents, reportable accidents and fatal accidents. As there were 50 respondents on dam site 50 respondents on highway site as well each one has different opinions or responses against a particular question so it was important to find the maximum answer or probability of maximum answer for a particular question to compute the results of 50 questionnaires and to classify the accidents into 4 classes the synthesis of data using *GUI* graphic user interface has been done. All the questions included in quessonnarie form were classified using synthesis of the responses filled by laborers, safety managers, site engineers, and engineer. For better data collection the quessonnarie has been made in two medium English and Hindi. The Hindi medium was generally used and filled by the laborers.

The synthesis process was done using GUI (graphic user interface) it can also be done manually but GUI is more time consuming and when the result was checked for the manual and GUI it was same. The framework of the work is mainly divided into two parts such as the accidents takes place during the construction of NTPC koldam hydro based power project and the accidents type during the construction of DAM.

There are two sheets in the project. The first sheet is all the questions which have been asked from different people. The second sheet is answers which is stored in form of 0 and 1. 1 for yes and 0 for no. Therefore the people who have marked on any one of the 4 options have been considered as 1 and for those questions which have not be occurred are mentioned as 0.

The algorithm for the synthesis procedure has been given below:

1) Read sheet data for all questions which is in form of 0 and 1 where 0 represents no and 1.
2) Bifurcate sheet of questions or quessonnarie form for dam and highway construction sites individually.
3) Display them into the GUI in different segments for two sites.
4) For each question in each type, there are four answers [21], [6]
   a) 'MINOR'
   b) 'REPORTABLE'
   c) 'MAJOR'
   d) 'FATAL'
5) Identify the question selected at the GUI and search the question in question sheet loaded at step 1
6) Extract all answers for that section particularly concentrating at the number of opinions which agree on yes and the once that agree on no.
7) Find all 1’s in the answer sheet filled by laborers, safety managers, site engineers and engineers.
8) For each 1 identify at which option 1 has been selected for minor, reportable, major or fatal.
9) For all answers, find maximum 1 neglecting 0.

Example for illustrating the synthesis process is given below;

1) Consider a question from quessonnarie form.
2) Accidents due to mental stress (exposure to a traumatic event, occupational violence, work pressure, suicide, attempt to suicide, workplace bullying)
3) Suppose the option count comes to be;

   (a) 3 respondents agreeing on this accident to be minor

   (b) 5 respondents agreeing on this accident to be reportable

   (c) 6 respondents agreeing on this accident to be major

   (d) 11 respondents agreeing on this accident to be fatal

4) The maximum value is for option 4 for question (Accidents due to mental stress (exposure to a traumatic event, occupational violence, work pressure, suicide, attempt to suicide, workplace bullying).

5) Hence the value would be FATAL and fatal option would be incremented by 1.

6) In such a manner for each question there would be an increment in the answer options.

In figure 3.5 a flowchart for segment of synthesis and fuzzy logic system is given. Firstly the data of accidents which occurred in past on site is collected from the dam and highway construction sites using quessonnarie form. Data sheets including the responses obtained in the quessonnarie form from site engineer, safety manager, engineer, labourers are generated in excel sheet in form of tick and cross and then converted in 0 and 1 where 0 represents cross and 1 represents cross for both highway and dam site respectively. Create graphic user interface in mat lab and add title as highway and dam site, identify the category of accidents. After this again load sheets of categorized accidents differently for dam and highway site in mat lab and apply fuzzy logic to the categorized accidents in order to determine the most critical accident on dam and highway construction, also to compare the rate of accidents on both highway and dam construction.

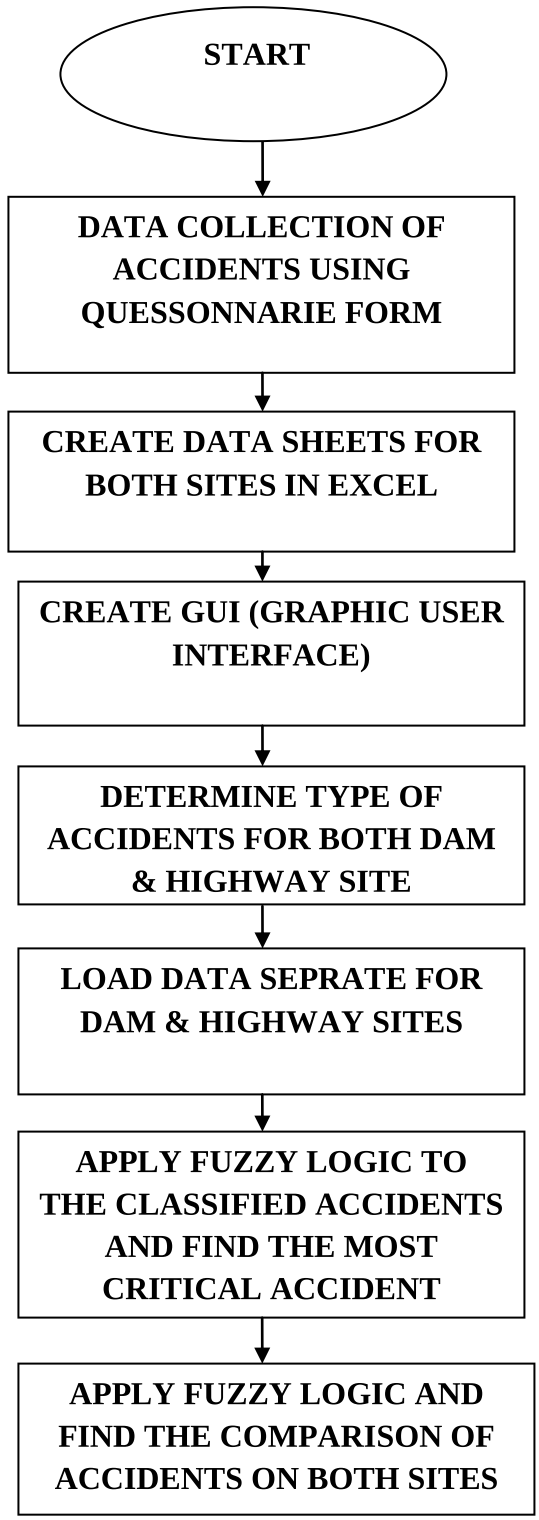


Figure 3.5 Sequential diagrams for synthesis and fuzzy logic

3.4.2 Implementations of Fuzzy Logic System

Once the accidents have been classified into minor, reportable, major & fatal category of accidents than this classification is used by fuzzy logic to determine the most critical accidents on both sites and also for the comparison of overall accidents on dam as well as highway sites. Fuzzy Logic (FL) is a reasoning method similar to human reasoning. Fuzzy logic system also makes it possible to take input as alphabetic or in number form and to give the outputs in form of numeric as well as alphabetic form. The FL approach mimics human decision-making, involving all intermediate possibilities between the numeric values YES and NO.

A fuzzy logic system is a nonlinear mapping of input data set to a scalar output data. Fuzzy logic not only takes data in form of binary numbers but also in other languages. Fuzzy logic system helps in determining the intermediate values for examples the in between values between 0 and 1.Fuzzy logic is used in this research for identifying the most critical factor for accidents amongst the all 20 accidents on both highway and dam construction which are concerned with finding the in between factor. The comparative analysis of two things or sites is also possible to determine through fuzzy logic system. Fuzzy Logic is applicable for practical and commercial purposes as defined below:

- It might not provide exact reasoning but suitable reasoning.
- It controls consumer and machine products.
- It helps for some uncertainty in engineering.

A Fuzzy logic system is generally used to derive the intermediate values in between 0 and 1 or 5 and 6 or in between any two numbers for *GUI* it is not possible to determine the intermediate values, it also helps in determining the probability for something. Fuzzy logic system generally consists of four elements as given below;

- Fuzzifier
- Rules
- Inference engine
- Defuzzier

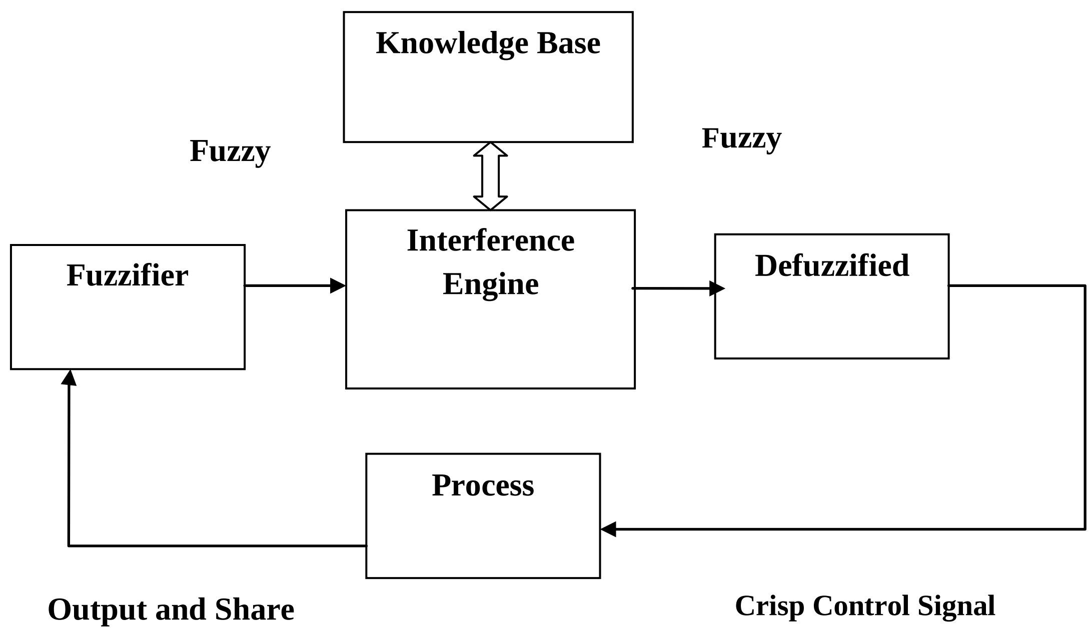


Figure 3.6 Framework of fuzzy logic

Figure 3.6 shows the architecture of fuzzy logic system or framework of fuzzy logic system. First step include a crisp set of input data are taken and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. The data is firstly defuzzified and the required data is extracted here. Once the data has been extracted the processing of the received data is done and it passed on to fuzzifier to attain the results or output on which fuzzy logic is applied. This tread is known as fuzzification. Later on, an inference is made based on a set of rules. Lastly, the resulting fuzzy output is mapped to a crisp output using the membership functions, in the defuzzification step. Various elements used in fuzzy logic system are given below;

1) Linguistic Variables

Linguistic variables are the input and output variables of the system input included the data of quessonnarie form and output is the outcome for finding the critical accident whose values are taken as words and sentences from a particular language, in place of numerical values. Linguistic variable make it possible to take data as numbers or alphabets A linguistic variable is generally breakup into a set of linguistic terms.

2) **Membership Functions**

Membership functions are comprehended in the fuzzification and defuzzifcation steps of a Fuzzy logic system, to map the non-fuzzy input values to fuzzy linguistic terms and conversely, in conversely. A membership function can also help in measuring a linguistic term. The membership functions for the linguistic terms variable can be shown as a combined plan. The most common types of membership functions are triangular, trapezoidal, and Gaussian shapes. As only three factors minor, reportable, major were used for the present proposed work so triangular membership function has been used in this research. If the factors are on which fuzzy logic is to be applied are more than four or is more complex at those places it is recommendable to use piecewise linear or Gaussian type of membership function.

There are different forms of membership functions;

- Triangular
- Trapezoidal
- Piecewise linear
- Gaussian
- Singleton

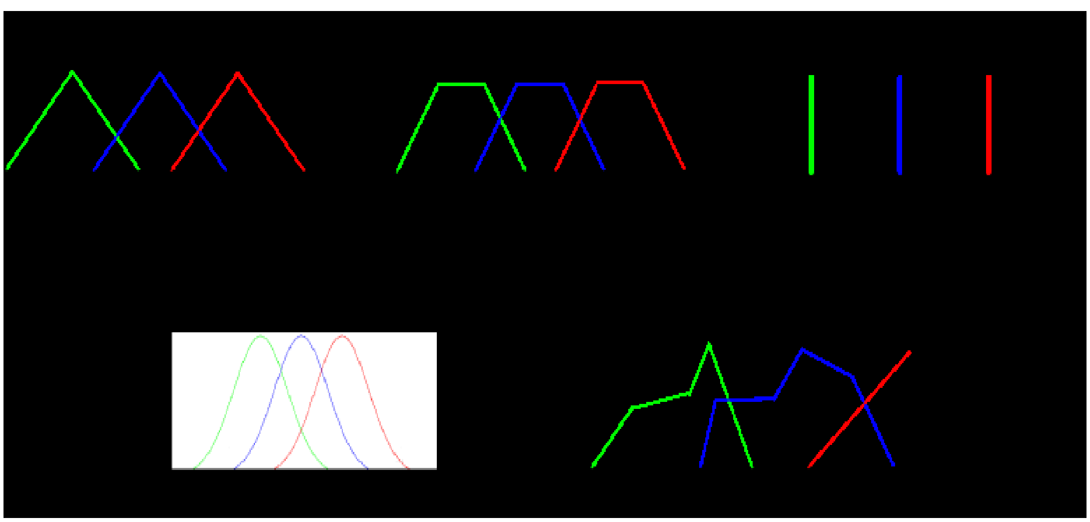


Figure 3.7 Types of membership functions

3) **Fuzzy Rules**

In a Fuzzy logic system, a rule base is plotted to restrict the production variable. A fuzzy rule is a simple IF-THEN rule with a prohibition and an interpretation. Fuzzy Set Operations the assessment of the fuzzy rules and the togetherness of the results of the individual rules are committed using fuzzy set operations.

Rule set used in the proposed work is shown below:

1. If(current lead is low) and (lead threshold is high) then (optimized lead is high)
2. If (current lead is high) and (lead threshold is low) then (optimized is mf1)
3. If (current lead is high) and (lead threshold is high) then (optimized lead is mf1)

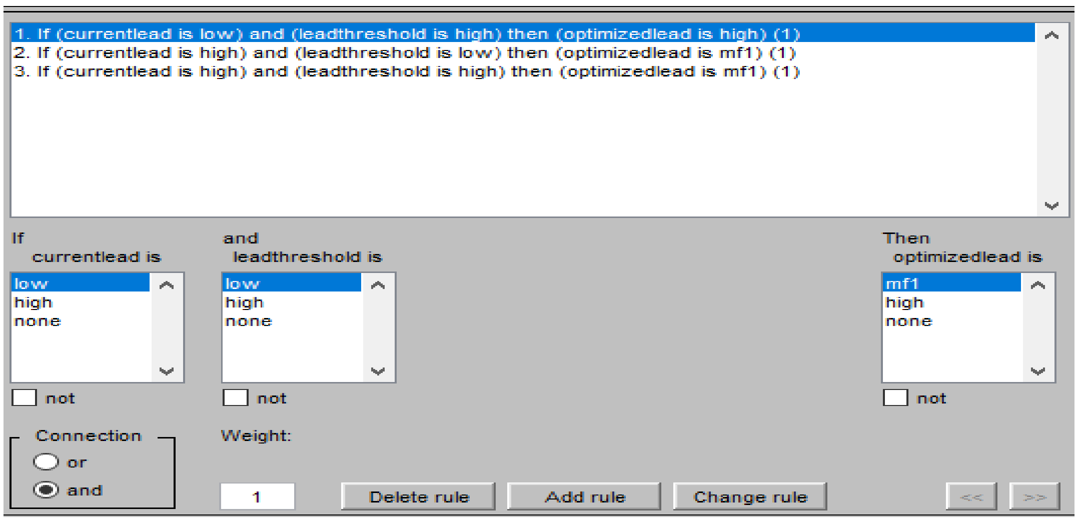


Figure 3.8 Rule editor [22]

As shown in figure 3.8 shows that if the current lead is low and lead threshold is high that results obtained will be high, if current lead is high and lead threshold is low that results obtained will be low, and if current lead is high and lead thresh hold is also high that results obtained will be low. Figure 3.9 represents the whole process of research work from the starting to the end. The input which is the current load value and the load threshold value is adjusted with the help of the red line. When the value of current load and lead threshold is 0.5 the output which is named as optimized lead is equal to 0.188 which is useful in obtaining the most critical accident on both the dam and highway site and the find the number of accidental rates on both sites.

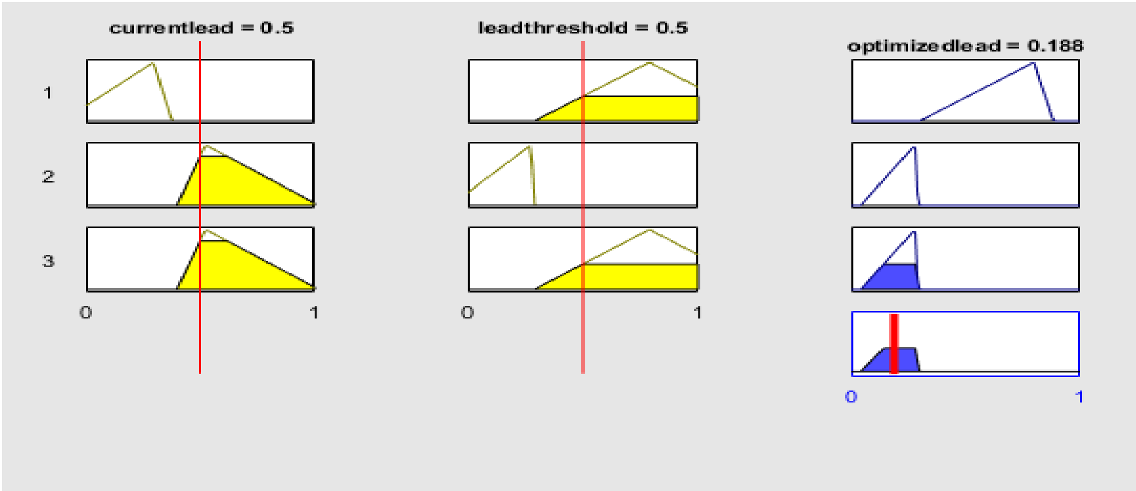


Figure 3.9 Rule viewer [22]

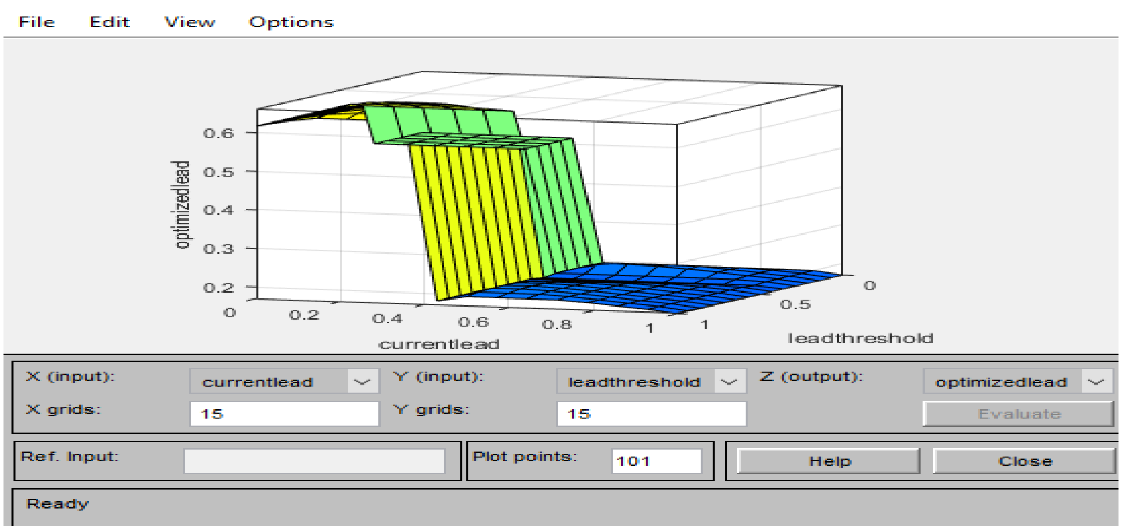


Figure 3.10 Surface viewers [22]

Figure 3.10 represents the surface viewer of the proposed work for the two inputs named as current lead and lead threshold. Here blue color represents the current lead and lead threshold values whereas yellow and green color represents the optimized values.

4) **Defuzzifcation**

Ulteriorly the inference step, the comprehensive conclusion is a fuzzy value. This conclusion should be defuzzified to draw end crisp output.

The algorithm for fuzzy logic is listed below;

1) Input is taken as data, threshold of data & Rule set. The data which is in the form of minor, reportable, major and fatal form obtained after synthesis is entered in to the rule set including the entire data.
2) Describe linguistic variables with the terms.
3) Develop membership functions as triangular for the rule set.
4) Create a knowledge base of rules.
5) Change crisp data into fuzzy data sets by utilizing membership functions. (Fuzzification occurs)
6) Calculate rules in the rule base. (Using Inference Engine)
7) Integrate outcome from every rule. (Using Inference Engine)
8) Change the output data in non-fuzzy values. (Finally, De-fuzzification occurs)
9) Output is received as optimized data defining the graph showing the most critical accident on site and also the number of accidents on site.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1General

As per delineated methodologies the processing was carried out in order to determine the various categories of the questions involved in quessonnarie form, to find the most critical accident on both dam and highway construction and for comparison in terms of accidents for both dam and highway sites.

4.2 Synthesis of Questionnaire Form

The data collected on both dam and highway site has to be cumulated in order to identify the maximum users for a particular option amongst the minor, reportable, major, and fatal against a particular question.

4.2.1 Various Percentages of Responses for Dam Site

Various percentage using GUI (graphic user interface) have been driven for all four classes of accidents are given in table 4.1 which divide the individual accident in perspective class of accident. Table include four sections which are minor reportable major and fatal. Where M1 represents minor, R represents reportable, M2 represents major and F represents fatal.

Table 4.1 Various percentages of responses for dam Site

DAM CONSTRUCTION				
QUESTIONS	**M1**	**R**	**M2**	**F**
1) Accidents in absence of higher or concerned authorities.	**100%**	0%	0%	0%
2) Accidents in absence of proper personnel protective equipment.	12.5%	**75%**	12%	0%
3) Accidents due to using defective equipments or disc cutters	**88.8%**	0%	11%	0%

4) Accidents due to improper loading or stacking and poor lifting techniques.	**100%**	0%	0%	0%
5) Accidents due to improper guarding and warning system.	**100%**	0%	0%	0%
6) Accidents due to access scaffolding.	10%	**100%**	0%	0%
7)Accidents due to falling of retaining walls.	**100%**	0%	0%	0%
8) Accidents where workers are under influence of drugs and alcohol.	0%	0%	0%	0%
9) Accidents due to falls, trips and slips of person from height.	**100%**	0%	0%	0%
10)Hitting stationary or moving objects with part of body.	**66.6%**	16%	16%	0%
11)Accidents due to sound and pressure.	**100%**	0%	0%	0%
12)Body stressing due to muscular stressing while lifting, carrying objects, repetitive moments, low muscle loading.	0%	**100%**	0%	0%
13) Accidents due to contact with heat and electricity.	**100%**	0%	0%	0%
14)Accidents due to environmental factors.	**50%**	25%	0%	25%
15) Accidents due to single or long term contact with chemical and other substances.	**100%**	0%	0%	0%
16) Accidents due to exposure or contact with biological factors.	**100%**	0%	0%	0%
17) Accidents due to mental stress (exposure to a traumatic event, occupational violence, work pressure)	**100%**	0%	0%	0%
18) Accidents due to vehicles (vehicles overturning, vehicles falling in excavation, person falling from vehicle).	**80%**	20%	0%	0%
19) Accidents due to confined spaces(lack of oxygen)	**50%**	50%	0%	0%
20) Accidents due to collapse of excavation, flooding of excavation.	**80%**	20%	0%	0%

As shown in Table 4.1, maximum of user responded accidents in absence of higher or concerned authorities to be minor, 88.8 % responded accidents due to using defective equipments or disc cutters to be minor whereas 11% responded this accident to be reportable, 100% responded accidents due to falling of retaining walls as minor accidents, 100% responded accidents due body stressing due to muscular stressing while lifting, carrying objects, repetitive moments, low muscle loading as reportable.

4.2.2 Various Percentages of Responses for Highway Site

Various percentage using GUI (graphic user interface) have been driven for all four classes of accidents, are given in Table 4.2, which divide the individual accident in perspective class of accident. Table include four sections which are minor reportable major and fatal. Where M1 represents minor, R represents reportable, M2 represents major and F represents fatal.

Table 4.2 Various Percentages of responses for Highway Site

HIGHWAY CONSTRUCTION				
QUESTIONS	**M1**	**R**	**M2**	**F**
1) Accidents in absence of higher or concerned authorities.	0%	0%	0%	0%
2 Accidents in absence of proper personnel protective equipment.	0%	**92.3%**	7.69%	0%
3) Accidents due to using defective equipments or disc cutters.	25%	**50%**	25%	0%
4) Accidents due to improper loading or stacking and poor lifting techniques.	**100%**	0%	0%	0%
5) Accidents due to improper guarding and warning system.	0%	0%	0%	0%
6) Accidents due to access scaffolding.	0%	**100%**	0%	0%
7)Accidents due to falling of retaining walls.	**100%**	0%	0%	0%
8) Accidents where workers are under influence of drugs.	0%	0%	0%	0%
9) Accidents due to falls, trips and slips of person from	0%	**100%**	0%	0%

height				
10)Hitting stationary or moving objects with part of body.	0%	**66.6%**	33.3%	0%
11)Accidents due to sound and pressure.	0%	**100%**	0%	0%
12)Body stressing due to muscular stressing while lifting, carrying objects, repetitive moments, low muscle loading.	0%	**100%**	0%	0%
13)Accidents due to contact with heat and electricity.	0%	0%	0%	0%
14)Accidents due to environmental factors.	20%	20%	**40%**	20%
15)Accidents due to single or long term contact with chemical and other substances.	0%	0%	0%	0%
16)Accidents due to exposure or contact with biological factors.	0%	0%	0%	0%
17) Accidents due to mental stress (exposure to a traumatic event, occupational violence, work pressure, suicide, attempt to suicide, workplace bulying).	**100%**	0%	0%	0%
18) Accidents due to vehicles (vehicles overturning, vehicles falling in excavation, person falling from vehicle).	30%	**70%**	0%	0%
19) Accidents due to confined spaces (lack of oxygen drowning).	0%	**100%**	0%	0%
20) Accidents due to collapse of excavation, flooding of excavation.	0%	**100%**	0%	0%

As shown in Table 4.2, 92.3% of respondents agree on accidents in absence of proper personnel protective equipment to be minor whereas 7.69% responded this accident as major, 66.6% responded on hitting stationary or moving objects with part of body to be reportable whereas 33.3% respondents marked this as major, 40% of respondents agree on accidents due to environmental factors as major whereas 20% of responses were in favor of minor, reportable and fatal, 100% of respondents agree upon accidents due to mental stress (exposure to a traumatic event, occupational violence, work pressure, suicide, attempt to suicide, workplace bullying) as minor accidents.

4.2.3 Categorization of Accidents on Dam Site

On basis of percentages derived from the data collection through quessonnarie form was used for categorization of a particular accident as minor, reportable, major, and fatal on dam site.

Table 4.3 Classification of dam accidents

QUESTIONS	DAM
1) Accidents in absence of higher or concerned authorities.	**Minor**
2) Accidents in absence of proper personnel protective equipment	**Reportable**
3) Accidents due to using defective equipments or disc cutters.	**Minor**
4) Accidents due to improper loading or stacking and poor lifting techniques.	**Minor**
5) Accidents due to improper guarding and warning system.	**Minor**
6) Accidents due to access scaffolding.	**Reportable**
7) Accidents due to falling of retaining walls.	**Minor**
8) Accidents where workers are under influence of drugs and alcohol.	**Minor**
9) Accidents due to falls, trips and slips of person from height or same level.	**Minor**
10) Hitting stationary or moving objects with part of body.	**Minor**
11) Accidents due to sound and pressure.	**Minor**
12) Body stressing due to muscular stressing while lifting, carrying objects, repetitive moments, low muscle loading.	**reportable**
13) Accidents due to contact with heat and electricity.	**Minor**
14) Accidents due to environmental factors.	**Minor**

15) Accidents due to single or long term contact with chemical and other substances.	**Minor**
16) Accidents due to exposure or contact with biological factors.	**Minor**
17) Accidents due to mental stress (exposure to a traumatic event, occupational violence, work pressure, suicide, attempt to suicide, workplace bulying).	**Minor**
18) Accidents due to vehicles (vehicles overturning, vehicles falling in excavation, person falling from vehicle).	**Minor**
19) Accidents due to confined spaces(lack of oxygen drowning).	**Minor**
20) Accidents due to collapse of excavation, flooding of excavation.	**Minor**

Table 4.3 shows the maximum accidents according to the questionnaire form filled by engineer, site engineer, safety managers and laborers were minor and very few of them were minor which include accidents due to single or long term contact with chemical and other substances person, accidents in absence of higher or concerned authorities, Accidents due to confined spaces (lack of oxygen drowning were minor accidents. Accidents due to access scaffolding, Body stressing due to muscular stressing while lifting, carrying objects, repetitive moments, low muscle loading, Accidents in absence of proper personnel protective equipment were classified as reportable with no major and fatal accidents.

4.2.4 Categorization of Accidents on Highway Site

On basis of percentages derived from the data collection through quessonnarie form was used for categorization of a particular accident as minor, reportable, major, and fatal on dam site. Table 4.4 shows the maximum accidents according to questionnaire form filled by engineer, site engineer, safety manager and laborers. Accidents such as due to single or long term contact with chemical and other substances, accidents in absence of higher or concerned authorities, Accidents due to improper guarding and warning system were classified as minor, accidents such as accidents due to using defective equipments or disc cutters, accidents due to sound and pressure were classified as reportable.

Table 4.4 Classification of highway accidents

QUESTIONS	HIGHWAY
1) Accidents in absence of higher or concerned authorities.	**Minor**
2) Accidents in absence of proper personnel protective equipment	**Reportable**
3) Accidents due to using defective equipments or disc cutters.	**Reportable**
4) Accidents due to improper loading or stacking and poor lifting techniques.	**Minor**
5) Accidents due to improper guarding and warning system.	**Minor**
6) Accidents due to access scaffolding.	**Reportable**
7)Accidents due to falling of retaining walls.	**Minor**
8) Accidents where workers are under influence of drugs and alcohol.	**Minor**
9) Accidents due to falls, trips and slips of person from height or same level.	**Reportable**
10) Hitting stationary or moving objects with part of body.	**Reportable**
11) Accidents due to sound and pressure.	**Reportable**
12) Body stressing due to muscular stressing while lifting, carrying objects, repetitive moments, low muscle loading.	**Reportable**
13) Accidents due to contact with heat and electricity.	**Minor**
14) Accidents due to environmental factors.	**Major**
15) Accidents due to single or long term contact with chemical and other substances.	**Minor**

16) Accidents due to exposure or contact with biological factors.	**Minor**
17) Accidents due to mental stress (exposure to a traumatic event, occupational violence, work pressure, suicide, attempt to suicide, workplace bulying).	**Minor**
18) Accidents due to vehicles (vehicles overturning, vehicles falling in excavation, person falling from vehicle).	**Reportable**
19) Accidents due to confined spaces (lack of oxygen drowning).	**Reportable**
20) Accidents due to collapse of excavation, flooding of excavation.	**Reportable**

4.3 Results of Fuzzy Logic

As previously discussed in methodology section the fuzzy logic is applied on the classified accidents on both sites to find the most critical accident and for comparative analysis.

4.3.1 Results of Fuzzy Logic for Dam Site

Figure 4.1 represents the dam optimization graph obtained after clicking on evaluate final button. From the above figure it is clear that for 1st, 3rd, 4th up to 7th questions stored into the database the user count or the accident count is near about 1. The user count obtained for 2nd question is approximately 2.3. Here x-axis represents the questions whereas y –axis represents the User count.

It is clear from the results of the optimization of dam that maximum accidents are due to Accidents in absence of proper personnel protective equipment (*PPE*). This can be due to negligence of the workers or may be due to the rules followed by the management in a particular firm or organization. Also accidents on the dam highway are less only up to question number 7 occurred on the site whereas other questions after 7th number can be ignored or considered negligible as these type of accidents have not been occurred on the dam construction site based upon the reposes filled.

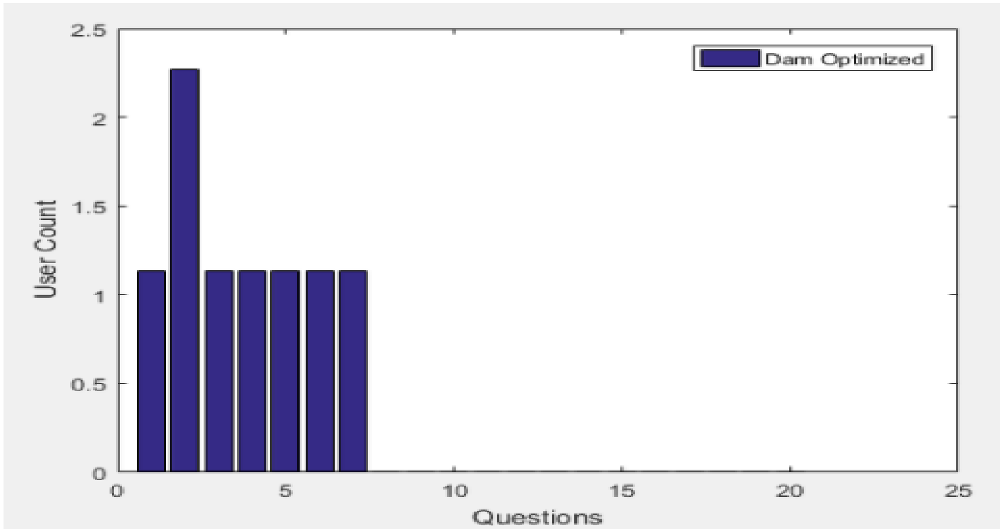
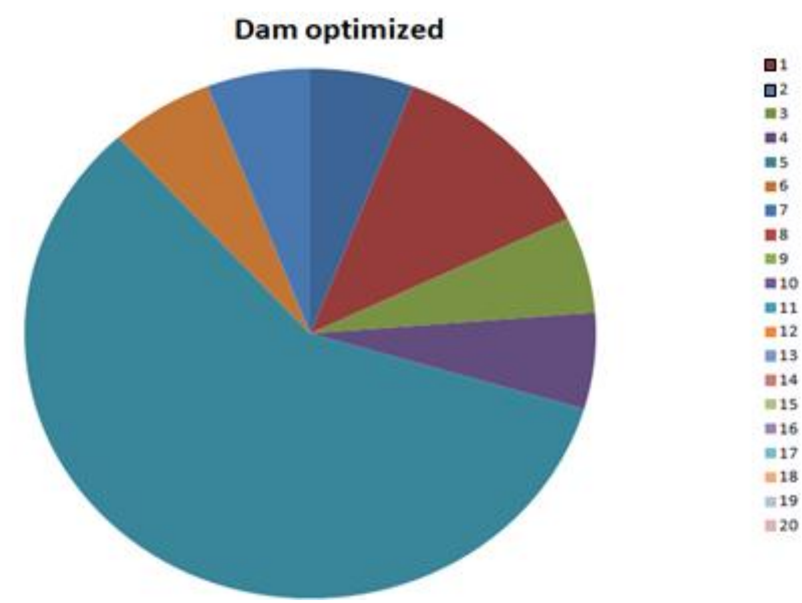


Figure 4.1 Most critical accident on Dam site (Accident vs. Respondents)

Figure 4.2 represents a pie chart for dam optimization which represents the various accidents which took place at highway site which include 20 sections each for one particular section. Maximum accidents occurring on the dam site are minor. the brown portion represents the accidents n absence of *PPE*. In the same sequence the other colors represent the various 19 questions



4.2 Pie chart for dam accidents

4.3.2 Results of Fuzzy Logic for Highway Site

Figure 4.3 displays the accidents on highway construction for the 20 questions collected from the highway construction site ((kiratpur to nerchowk highway). Here x-axis represents the questions whereas y –axis represents the User count. From the above figure it is clear that the user count for the second question (Accidents in absence of proper personnel protective equipment) is high. Whereas for 1st, 3rd, 4th, 5th and 6th questions the user cunt is one. Above 6th questions the user count is very small near to zero.

It is clear from the results of the optimization of dam that maximum accidents are in absence of proper personnel protective equipment. The occurrence of accidents on the highway construction is more as compared to the highway site as some accidents are negligible in dam construction whereas the accident on the highway construction are greater to 0 so they cannot be ignored.

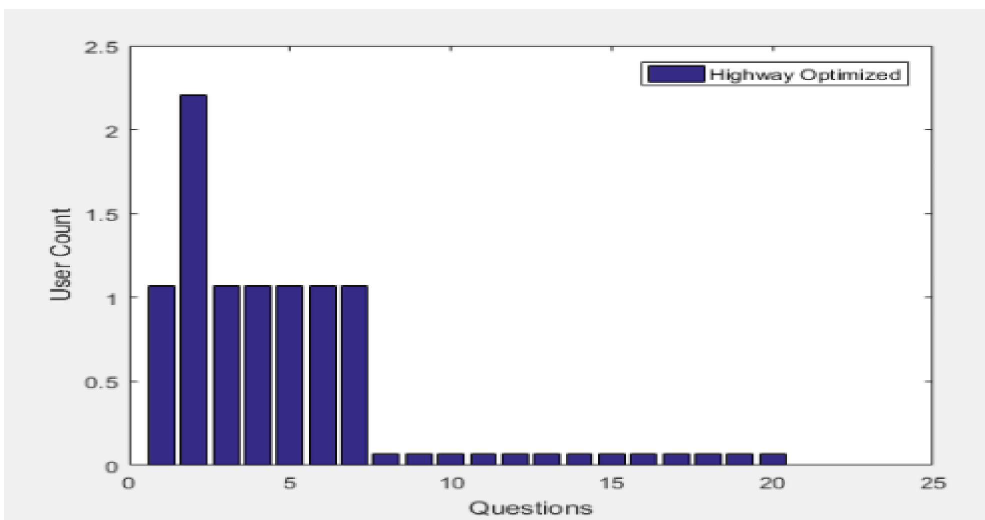


Figure 4.3 Most critical accident on Highway site (Accident vs. Respondents)

The occurrence of accidents is more in highway construction as shown in the pie chart and bar graph for the various questions. By implementing procedures for personnel protective equipment at sites cost and time of project can directly be controlled. As indirect cost involved in the treatment of laborers, the hospital expenses, extra laborers cost can be deducted and time delay can also be avoided by taking measures to avoid accidents in absence of *PPE.*

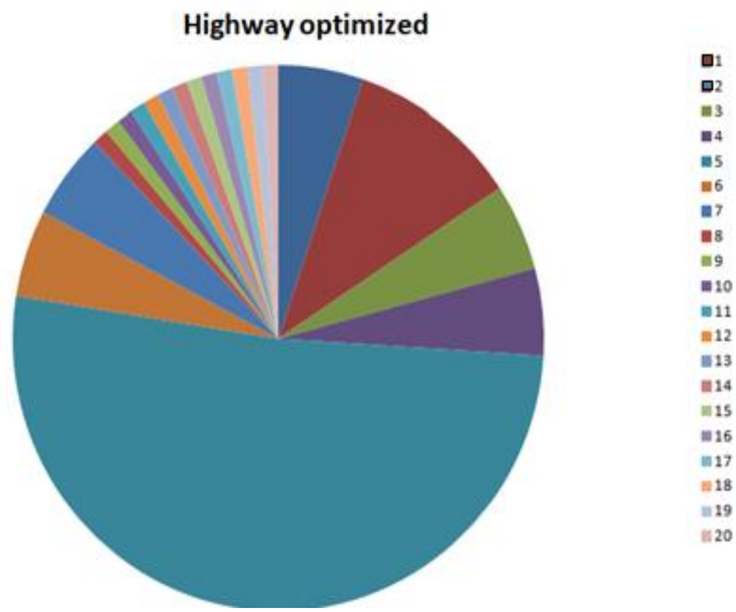


Figure 4.4 Pie chart for highway accidents

Figure 4.4 represents a pie chart for highway construction site which shows the various accidents which took place at highway site which include 20 sections each for one particular question. This pie chart is made upon the approximate identification from the fuzzy logic system. The accidents occurring on highway site are more so the pie chart include 20 sections each one for a particular question. The accidents in absence of PPE are more.

CHAPTER 5

CONCLUSIONS

5.1 General

The section deals with the conclusion of research on identification and comparison of accidents which includes benefits through research in cost as well safety along with the future scope of the research.

5.2 Conclusions

From the results obtained using Questionnaire method, its data synthesis and optimization using Fuzzy logic, following conclusions can be derived:

- From quessonnarie form most occurring accidents on the highway and dam site were due to improper supervision, faulty equipment and due to environmental factors.
- It can be concluded from the quessonnarie method that at both dam & highway sites the affect of environmental factors is classified as the major category of accidents also accidents due to defective equipments & failure of construction equipments & unsupervised construction activities are minor reason of accidents. Moreover accidents in absence of personnel protective equipments, falls, trips& slips of individuals at construction sites & due to vehicle accidents are treated as reportable accidents.
- From fuzzy logic applied to the accidents as fatal, major, reportable, minor it can be concluded that on both dam & highway construction sites, accidents in absence of personnel protective equipments are found to be the most critical accident.
- The comparison of dam and highway sites further reveals occurrences of greater number of accidents at highway site. However PPE was found as the most critical accident on both sites.

- Moreover it can also be inferred that identification & rectification of the most critical factor accident that is in absence of personnel protective equipment will help in reducing the indirect cost of the project thus rendering it economical.
- Further, a remedial measure to rectify PPE (personnel protective equipment) can be done by doing a hazard assessment on the site, appointing a safety manager who keeps a check about regular training and maintenance about PPE to the workers and the entire construction staff.

5.3 Scope for Future Work

There is a wide scope of research in the field of identification and comparison of accidents. So present work can be further extended to evaluate some of the objectives as given below:

- As two sites which are highway and dam sites have been considered in the thesis in future other sites such as residential building, commercial buildings, industrial buildings can be also included in the research.
- The number of factors for making the questionnaire form can also be increased and proportionally the respondents for filling the quessonnarie form can also be increased.
- GA (genetic algorithm) can also be used to determine the most critical accident and for the comparison purpose than the results can be compared with the results of fuzzy logic system.

References

1) Winanda L. A. R., Adi T. W., Anwar N., & Wahyuni F. S. (2017, November). Construction safety monitoring based on the project's characteristic with fuzzy logic approach. In *AIP Conference Proceedings* (Vol. 1903, No. 1, p. 070009). AIP Publishing.
2) A. S., & Priyadarshini K. "Safety management and hazard control measures in construction" *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X. PP 97-101*
3) Carter G., Smith S. D. (2006). Safety hazard identification on construction projects. *Journal of construction engineering and management*, *132*(2), 197-205.
4) Hamid A. R. A., Majid M. Z. A., & Singh B. (2008). Causes of accidents at construction sites. *Malaysian journal of civil engineering*, *20*(2), 242-259.
5) Zhang L., Skibniewski M. J., Wu X., Chen Y., & Deng Q. (2014). A probabilistic approach for safety risk analysis in metro construction. *Safety science*, *63*, 8-17.
6) Holt A. S. J. (2008). *Principles of construction safety*. John Wiley & Sons. No. pp. 9.
7) Chong H. Y., & Low T. S. (2014). Accidents in Malaysian construction industry: statistical data and court cases. *International journal of occupational safety and ergonomics*, *20*(3), 503-513.
8) Kumar S. & Joshi D.A. (2016). Risk Management in BOT. *International Journal of Scientific Research and Management*, *4*(9).

9) Awolusi I. G. & Marks E. D. (2016). Safety activity analysis framework to evaluate safety performance in construction. *Journal of Construction Engineering and Management*, *143*(3), 05016022.

10) Shivam P., & Kumar M. (Nov-2015). "To study risk management in construction management for developing countries" volume-4, *issue-11, ISSN No. 2277-8160*

11) Carr V. & Tah J. H. M. (2001). A fuzzy approach to construction project risk assessment and analysis: construction project risk management system. *Advances in engineering software*, *32*(10-11), 847-857.

12) Wu X., Liu Q., Zhang L., Skibniewski M. J. & Wang Y. (2015). Prospective safety performance evaluation on construction sites. *Accident Analysis & Prevention*, *78*, 58-72.

13) Ghaderi R. & Kasirossafar M. (2011). Construction safety in design process. In *AEI 2011: Building Integration Solutions*(pp. 464-471).

14) Alinaitwe, Henry J. Mwakali & Bengt Hansson, "Analysis of accidents on building construction sites reported in Uganda during 2001–2005." *CIB World Building Congress, Construction for Development*. 2007.

15) Goh Y. M. & Chua S. (2016). Knowledge, attitude and practices for design for safety: A study on civil & structural engineers. *Accident Analysis & Prevention*, *93*, 260-266.

16) Zou P. X. & Sunindijo R. Y. (2013). Skills for managing safety risk, implementing safety task, and developing positive safety climate in construction project. *Automation in Construction*, *34*, 92-100.

17) Majumder D., Debnath J. & Biswas A. (2013). Risk analysis in construction sites using fuzzy reasoning and fuzzy analytic hierarchy process. *Procedia Technology*, *10*, 604-614.

18) Graydon P. J. & Holloway C. M. (2017). An investigation of proposed techniques for quantifying confidence in assurance arguments. *Safety science*, *92*, 53-65.

19) Mattila M., Hyttinen M. & Rantanen, E. (1994). Effective supervisory behaviour and safety at the building site. *International Journal of Industrial Ergonomics*, *13*(2), 85-93.

20) Asanka W. A. & Ranasinghe M. (2015). Study on the impact of accidents on construction projects. In *6th International Conference on Structural Engineering and Construction Management, Kandy, Sri Lanka*, *11th-13th December*.

21) Raviv G., Shapira A. & Fishbain B. (2017). AHP-based analysis of the risk potential of safety incidents: Case study of cranes in the construction industry. *Safety science*, *91*, 298-309.

22) MATLAB version 6.5.1, (2017), (computer software), The Mathworks Inc., Natick, Massachusetts.

23) "Safety and health in construction", *An ILO code of practice Geneva, International Labour Office*, (1992) ISBN 92-2-107104-9

24) Google.image."https://www.google.co.in/maps/dir/Jaypee+University+of+Information+Technology,+Waknaghat,+Himachal+Pradesh+173234/NTPC+KOLDAM,+Chamyon,+Himachal+Pradesh+174013" (2005)

25) Google.Image."<https://www.google.co.in/maps/dir/Jaypee+University+of+Information+Technology,+Waknaghat,+Himachal+Pradesh+173234/sundernagar"(2005)

26) Google.Image.https://www.google.com/search?tbm=isch&q=accidents+at+dam+construction+site&chips=q:accidents+at+dam+construction+site,online_chips (2007)

APPENDIX

APPENDIX A

Quessonnarie and Respondents

A 1) Quessonnarie for both sites in English

1) Accidents in absence of higher or concerned authorities
2)Accidents due to using defective equipments or disc cutters
3) Accidents in absence of proper personnel protective equipment
4) Accidents due to improper loading or stacking and poor lifting techniques
5) Accidents due to improper guarding and warning system
6) Accidents due to access scaffolding
7) Accidents due to demolition (exposure to excessive noise, striking overhead or underground services)
8) Accidents where workers are under influence of drugs and alcohol
9) Accidents due to falls, trips and slips of person from height or same level
10)Hitting stationary or moving objects with part of body
11)Accidents due to sound and pressure
12)Body stressing due to muscular stressing while lifting, carrying objects, repetitive moments, low muscle loading
13)Accidents due to contact with heat and electricity
14)Accidents due to environmental factors
15)Accidents due to single or long term contact with chemical and other substances
16)Accidents due to exposure or contact with biological factors
17)Accidents due to mental stress (exposure to a traumatic event, occupational violence, work pressure, suicide,attempt to suicide, workplace bulying
18)Accidents due to vehicles (vehicles overturning, vechiles falling in excavation,person falling from vehicle
19)Accidents due to confined spaces(lack of oxygen drowning)
20)Accidents due to collapse of excavation, flooding of excavation

A2) Quessonnarie for both sites in Hindi

1) उच्च या संबंधित प्राधिकरणों की अनुपस्थिति में दुर्घटना
2) उचित पीपीई (कर्मियों के सुरक्षात्मक उपकरण) की अनुपस्थिति में दुर्घटनाएं
3) दोषपूर्ण उपकरणों या डिस्क कटर का उपयोग करने के कारण दुर्घटनाएं।
4) गलत लोडिंग या स्टैकिंग और खराब उठाने तकनीक के कारण दुर्घटनाएं।
5) अनुचित रक्षा और चेतावनी प्रणाली के कारण दुर्घटनाओं।
6) मचान का उपयोग करने के कारण दुर्घटनाएं
7) विध्वंस (अत्यधिक शोर, हड़ताली ऊपरी या भूमिगत सेवाओं के संपर्क में) के कारण दुर्घटनाएं
8) दुर्घटनाओं जहां मजदूर दवाओं और शराब के प्रभाव में हैं
9) ऊंचाई या समान स्तर से गिरने, यात्राएं और व्यक्ति की फिसल जाने के कारण दुर्घटनाएं।
10) शरीर के हिस्से के साथ स्थिर या चलती वस्तुओं को मारना।
11) ध्वनि और दबाव (अचानक ध्वनि, विस्फोट और दबाव में अन्य भिन्नता के संपर्क में) के कारण दुर्घटनाएं
12) मांसपेशियों को उठाने, वस्तुओं को ले जाने, दोहरावदार क्षण, कम मांसपेशी लोड हो रहा है
13) गर्मी और बिजली के संपर्क के कारण दुर्घटनाएं
14) पर्यावरणीय कारकों के जोखिम के कारण दुर्घटनाएं
15) रसायनों और अन्य पदार्थों के साथ एकल या दीर्घकालिक संपर्क के कारण दुर्घटनाएं।
16) जोखिम के कारण दुर्घटनाओं या जैविक कारकों के साथ संपर्क।
17) मानसिक तनाव के कारण दुर्घटनाओं (एक दर्दनाक घटना के संपर्क में, व्यावसायिक हिंसा, काम का दबाव, आत्महत्या, आत्महत्या करने का प्रयास
18) वाहनों के कारण दुर्घटनाएं (वाहनों को उलट करना, उत्खनन में पड़ने वाले वाहन, वाहन से गिरने वाला व्यक्ति
19) सीमित स्थान (ऑक्सीजन की डूबने की कमी) के कारण दुर्घटनाएं
20) उत्खनन के पतन, उत्खनन के बाढ़ के कारण दुर्घटनाएं

A 3) Quessonnarie data obtained from Dam Sites

RESPONDANT 1			
MINOR	REPORTABLE	MAJOR	FATAL
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–

RESPONDANT 2			
MINOR	REPORTABLE	MAJOR	FATAL
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–

RESPONDANT 3			
MINOR	REPORTABLE	MAJOR	FATAL
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–

RESPONDANT 4			
MINOR	REPORTABLE	MAJOR	FATAL
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–

RESPONDANT 5			
MINOR	REPORTABLE	MAJOR	FATAL
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–

A 4) Quessonnarie data obtained from Highway Site

RESPONDANT 1			
MINOR	REPORTABLE	MAJOR	FATAL
–	–	–	–
✓	–	–	–
✓	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–

RESPONDANT 2			
MINOR	REPORTABLE	MAJOR	FATAL
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	✓	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–

RESPONDANT 3			
MINOR	REPORTABLE	MAJOR	FATAL
–	–	–	–
–	✓	–	–
–	✓	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	✓	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–

RESPONDANT 4			
MINOR	REPORTABLE	MAJOR	FATAL
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–

RESPONDANT 5			
MINOR	REPORTABLE	MAJOR	FATAL
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
✓	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–
–	–	–	–