PREDICTING SAFETY STRUCTURE OF INFRASTRUCTURE PROJECTS THROUGH NEURAL NETWORK IN MATLAB

A

THESIS

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

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Under the supervision

of

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by

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

May – 2021

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"Predicting Safety Structure of Infrastructure Projects Through Neural Network In MATLAB"** submitted for partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering with specialization in Construction Management at **Jaypee University of Information Technology, Waknaghat,** is an authentic record of my work carried out under the supervision of **Dr. Saurabh Rawat.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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May - 2021

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Predicting Safety Structure of Infrastructure Projects Through Neural Network In MATLAB"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in Construction Management submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Rahul Garg, 192602** during a period from June, 2020 to May, 2021 under the supervision of **Dr. Saurabh Rawat** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

Date: 14-May-2021

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May - 2021

ABSTRACT

At construction site safety of the employees and laborers is a very big answerability. Project management needs to take remedial measures to reduce accidents. In this research, Neural Network is developed in MATLAB to foreshow the safety structure of the infrastructure projects. Factors affecting safety are identified by expert opinions. By using safety factors questionnaire is formed and survey form distributed among various Site Managers, Engineers, Site Supervisors, and laborers. Out of 282 responses, 252 were considered for the development of ANN, and 32 were used for validation of the model. Average index is calculated for each factor affecting safety. 60%-20%-20% is used as the distribution ratio of samples for the training, validation, and testing process. A feed-forward back propagation network is used. Levenberg-Marquardt is used as a training algorithm rather than Bayesian Regularisation, and scaled conjugate gradient. 14 Hidden neurons were found satisfactory for the network. Network 10-14-1 is found satisfactory for Artificial Neural Network Model. By Using the SPSS value of Cronbach's alpha coefficient found to be 0.72 which indicates collected data is reliable. Model is validated by using MAPE. The value of 4.623% found for MAPE. Factor analysis was performed to categorized and ranked factors according to communalities values. Guidelines are suggested at the end so that safety performances at the construction site can be improved. The model can help management in predicting and monitoring safety performances of the construction projects. Site accidents can be reduced with the help of this model and management can achieve a good safety record.

Keywords: Accident, Safety Climate, Neural Network, Prediction, MATLAB, Risk Management.

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LIST OF ACRONYMS & ABBREVIATIONS

Acronym	**Caption**
APD	Absolute percentage Deviation
ANN	Artificial Neural Network
CI	Construct index
GI	General Influence
SEM	Structural Equation Modeling
OR	Overfitting ratio
SPSS	Statistical package for the social sciences
MAPE	Mean Absolute Percentage Error
FA	Factor Analysis
COC	Coefficient of Correlation

CHAPTER 1

INTRODUCTION

1.1 General

The project working site is the dangerous workplaces in every industry. Comparing construction industry with other industries, the construction industry has poor safety record. Most accidents at construction sites happen due to unsafe design and acts of their employees. Unsafe acts of employees at the construction site can lead to injury, time overrun, and loss of life. Various factors occur at construction projects which involve unsafe practices. Accidents at the construction site happen due to lack of supervision, inattention, and lack of training. Every project is different and for every project risk factors can vary. Sometimes due to unsafe practices and behavior project can delay its completion and also go into heavy loss. Fig. 1.1 showing the negative effects of unsafe work behavior.

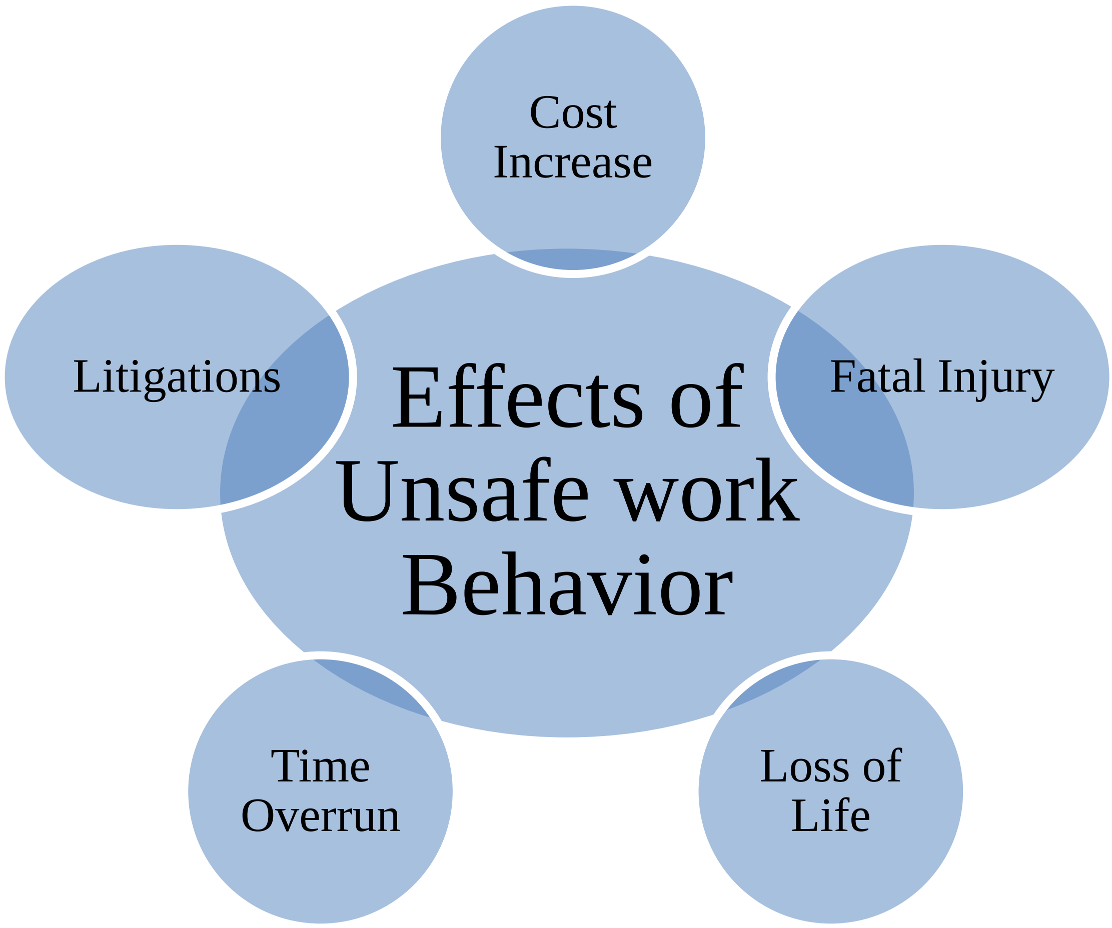


Figure 1.1 Effects of unsafe work Environment

In construction projects, unsafe behavior found to be a most significant factor which causes site accident and indicate poor safety culture. Therefore it is essential to predict the safe work environment in construction projects.

In construction projects ensuring zero accidents at the construction site is a challenging task. Also due to unsafe acts, it becomes a challenging task for the company to complete the project on time and also within the estimated budget. Sometimes accidents cause higher overhead costs to construction companies due to longer construction periods. The unsafe act caused by workers can create a political, social, and economic outcome for the countries where the construction is happening.

Artificial Neural Network (ANN) may be used for predicting the safe work environment in the construction site. Predicting a safe work environment before starting work will identify the weaknesses and will be useful for adopting safety measures before the occurrence of an accident. This will help in improving safety management practices at the construction site.

1.2 Need of Study

1. Most accidents at construction site happen due to unsafe act of their employee at site and it become important for the project team to minimize these factors.
2. The main objective of this research is to recognize safety causes affecting construction projects and make a Neural Network that can predict a safe work environment at construction sites.
3. The basic idea behind this study was to constitute a neural model which can tell a safe work environment at the infrastructure project site so that weaknesses can be recognize at the construction site and safety measures can be adopted before the occurrence of an accident at the construction workplace.
4. Managing risks in effective manner can reduce accidents at site and also achieve less construction cost and completion time frame.
5. Recommendations will be suggested to improve safety at the construction site.

1.3 Artificial Neural Network

An ANN is a chain of algorithms that try to identify fundamental connections in a group of data through a method that copying the way the human brain work. Neural Networks are artificial in nature. ANN can predict linear and non-linear data relationships.

Neural Networks have the ability to change input, so that the best possible results can be generated without redesigning the output criteria.

Artificial neural networks are used in a variety of applications in risk assessment, forecasting, and marketing research. Artificial Neural Network consists of layers of interconnected nodes. Neural networks take data input and train themselves to recognize patterns. An artificial neural network (ANN) predicts output for a similar set of data.

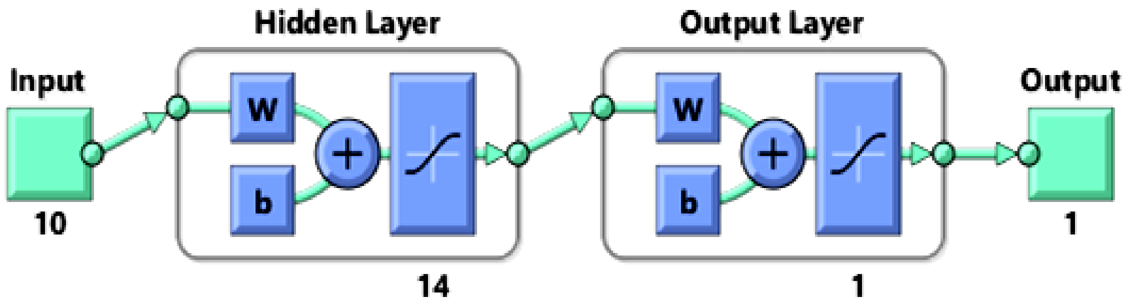


Figure 1.2 Representation of Input-Hidden-Output layer

In Artificial Neural Networks layers are connected through the channel and each channel has a numerical value known as weight. Each input has a value known as bias. The value passes through the activated function and then the output layer will predict the output. If the output layer does the wrong prediction then the information process backward known as back propagation and based on this information weights are adjusted. The process continues until results come true.

There are various advantages of the artificial neural network over other methods due to its extraordinary features. They are superior in recognizing difficult relations in a group of data and are also capable of resolving nonlinear relationships. These ANN have the capability to set their numeric weights automatically. The alternative methods of Artificial Neural Networks are given in Table 1.1.

Table 1.1 Alternative methods to ANN

Alternative Methods	**Weaknesses**
Regression Method	It requires clear description of connection in statistical model. This method is not adherent for difficult non linear mapping.
Structural Equation Modeling	Multitude of parameter are estimated simultaneously. Not take raw data as input information.

1.4 Factors Affecting Safety at Construction Site

Various factors affecting safety practices of construction workers on project site. Table 1.2 showing the factors which are involved in affecting safety at construction projects. The safety factors are categorized according to their risk groups. These safety factors are also used in this study and safety factors according to their group are listed in Fig. 1.3.

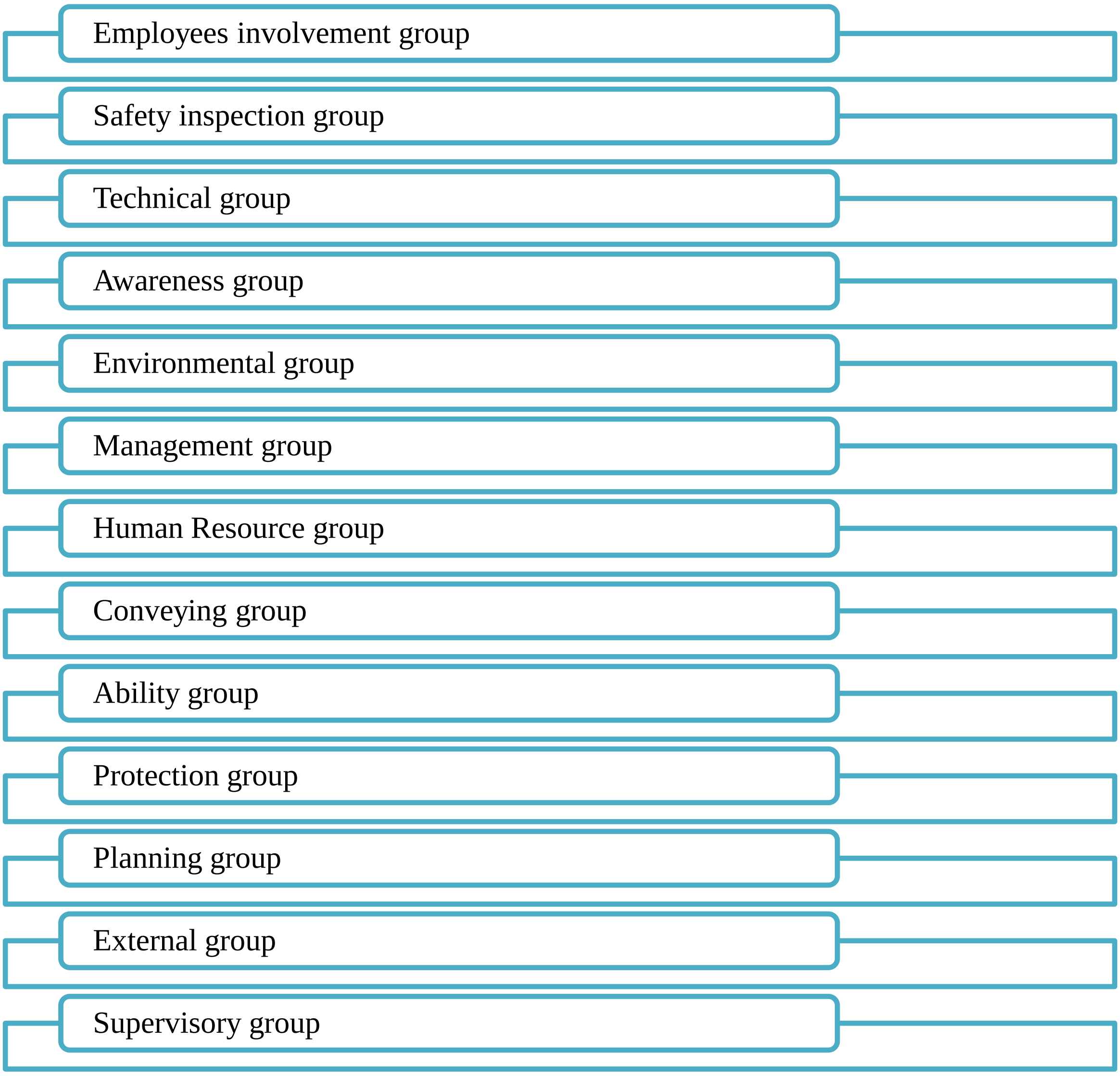


Figure 1.3 Risk groups involved in affecting safety at construction site

Based on the risk groups statements are made in terms of questions. Safety factors which are involved in affecting safety are shown in Table 1.2.

Table 1.2 Factors influencing safety at construction site.

Sr. No	Description of Factors/Statement
1	Improper Planning
2	Poor Coordination between workers
3	Lack of engagement in safety talks
4	Unsafe behavior done by co-workers
5	Completion time of work
6	Poor site layout
7	Lack of responsibilities
8	Equipment Deficiency
9	Weather conditions
10	Unclear about responsibilities for safety
11	Lack of knowledge about basic safety rules
12	Employee education level
13	Lack of accident investigation
14	Working individually in risky environment
15	Safety inspection before starting work
16	Lack of skilled management
17	Poor control on employees for working unsafely

18	Use of defective Equipment
19	Less use of advance equipments
20	Inexperience operators for heavy machinery
21	Not organizing campaigns to promote safe working practices
22	Not providing safety information to site employees
23	Incapable of identifying potentially hazardous situations
24	Not using protective equipments
25	Lack of safety training

1.5 Software

Two software which are used in this research are SPSS and MATLAB.

1.5.1 SPSS (Statistical Package for Social Science)

SPSS is mostly used for statistical data analysis. SPSS is the best software for survey data analysis. It offers four programs named as Modeler program, Statistics program, Text Analysis, and Visualization Designer for various data analysis needs. There are various tests available to perform reliability tests like Cronbach's alpha, k, T-test, and one-way Anova test.

1.5.2 MATLAB

The software which is used to develop the Neural Network model is MATLAB. Neural Network fitting app in MATLAB is selected for the development of the model. In fitting problems, Neural network map the dataset between given input and output value. Three layers are used in the neural network model named Input, Hidden and output layer. Input and target values are added in the first section from the file section and after adding input and target values samples are divided for the training phase, validation phase, and testing phase. The number of Hidden Neurons is selected based on trial or when the root mean square error comes out to be less. The training algorithm is selected after selecting the number of neurons. Based on desired results performance of the network can be checked.

1.6 Outline of Thesis

The research is organized into six chapters. The appendix part is also included at the end of the chapter which shows the calculation part of the research. A short description of the chapters is described below

1. **Introduction:** In this chapter different risk factors affecting safety are discussed. The neural network, an alternative method to neural network also discussed in this.
2. **Literature Review:** In this chapter factors affecting safety are determined. Various neural network methods are also discussed in this chapter.
3. **Methodology:** In this chapter, the research process is discussed. The choice of architecture, the selection of hidden neurons, and the selection of training algorithms are discussed.
4. **Analysis:** In this part value of the Average index is calculated and a neural network is developed.
5. **Result and Discussion:** In this chapter, research findings are discussed in detail.
6. **Conclusions and Guidelines:** In this part conclusions and guidelines are discussed.

References

Appendix-A: Questionnaire survey

Appendix-B: Questionnaire survey Hindi

Appendix-C: Input values for model

Appendix-D: Factor analysis

CHAPTER 2
LITERATURE REVIEW

2.1 General

A numerous studies have conducted out to outline cause of delay in infrastructure projects.

Cheung et al., [1] developed a Neural Network-based prediction model for predicting project performance. The multi-layer-perception framework of Neurosolution software was used in this research. For input, information from the tender report was used and for output variable record of the successful bidder in construction was used. ANN for the prediction of project performance scores for work found to give the highest hit rate and “Difference between Estimate” and “Difference between the next closest bid” are the most sensitive input variable toward such predictions. The difference between the actual value and predicted value was used as a measure to find the result is satisfactory or not.

Fang et al., [3] conducted research to achieve component of the safety of Gammon to reform the safety environment on site. The study used a questionnaire survey for extracting safety climate dimensions. By factor analysis, 15 factors as safety climate dimensions have been extracted. Moreover, Regression was applied for analyze the connection between safety component and personnel features. The results indicate that with enhanced responsibilities employee will have more experience of their work. Learning level and safety intelligence are the crucial component for safety factors.

Azadeh et al., [4] proposed a Neural approach for assessing and developing job saturation with considering HSE. A questionnaire survey was used to achieve this objective and filled by operators. The result of ergonomics HSE used as input for model and satisfaction of job as target. Adaptive Neural Network used to rank performance according to satisfaction of job and HSE ergonomics. To identify outliner operator Normal Probability Technique is used.

Sawacha et al., [5] conducted a study to define element affecting safety functions on sites. Technical, procedural, Economical and psychological factors are determined as those factors which have a direct link with the level of safety. The psychological factor is assessed by the safety behavior of worker and organizational factor is assessed by the policy that company management adopt to provide site safety. Moreover, Factor analysis is used which conclude that variable under the organizational policy is most dominant factors influencing safety performances at the construction site.

Chakraborty et al., [6] generate a pedestrian crash forecasting model founded on an artificial neural network. For making artificial neural network ANN three activated functions are used. Four learning algorithms are used in the development of ANN. The number of hidden neurons is selected by performing trials various times to get the better outcomes. Sensitivity analysis is used to find the most significant factors.

Mohamed, [7] examine the relationship between constituents of safety and safe work dealing on construction sites. Various components having ability to possess safety component have been identified using literature. The questionnaire was used for collecting information from various project sites. The results are tested using Structural Equation Modeling. As a result 10 safety climate construct are determined. Work pressure was found to have no significant relation with safety climate. An indirect negative relationship to safety climate is found and impacts workers willing to take time-saving shortcuts.

Choudhary et al., [8] determine a safety climate that improves safety culture. A safety climate questionnaire survey from various construction companies was used to collect information. Two safety climate factors were extracted using factor analysis. Multiple regression was used for predicting significant factors of worker's perception of safety performances. “Inappropriate safety procedure and work practices” and “Employee involvement and management commitment” are found to be significant predictors of employee's safety performances. The relationship between safety performances and inappropriate safe procedures is found inversely correlate. Safety components can be used as an effective measure for improving site safety for undergoing construction.

Heravi and Eslamdoost, [9] developed a labor productivity model for mapping the components to labor productivity is conducted. The network was trained with a backpropagation algorithm. Change in productivity of labor is the result of various impacting components. Bayesian regularization and early stopping are implemented to prevent networks from overfitting. Sensitivity analysis is conducted to know the top influential component. Artificial Neural Network is developed which can predict labor productivity. Bayesian regularization has been found to have better performance than early stopping. Improper planning, poor decision making, improper site layout, and labor competence are determined as the most influencing factors.

Molenaar et al., [10] performed an analysis on system of safety and its influence on site performances. The structural equation model described the relationship between safety performances and safety culture. Questionnaire responses are used to estimate the structural equation model. People, processes, and values are found as characteristics of safety culture. Using structural equation model 5 variables are identified which describe safety culture. SEM suggests safety culture as an important aspect of safety performance.

Tadesse et al., [11] developed a Neural Network for predicting deflection at service load in steel bridges. Three Neural Networks are presented which cover Two and Three-span continuous bridges and simply support bridges. ABAQUS a finite software is used to train and test data for Neural Network Model. Based on Neural Network closed-form solutions are formed. Six bridges as an example are considered to exhibit Neural Network applications. The number of parameters for bridge spans simply support and two and three spans are 3, 7 and 8 respectively.

Alruqi et al., [12] conducted an analysis that determines construction system affecting safety dimensions that can predict future injuries. A questionnaire survey was applied to get safety component dimensions in the construction industry. Various components of safety system are identified using a literature review. 14 site safety components identified as mostly used safety component. Safety rules and procedures were found to have a moderate effect on injuries.

Chiou, [13] developed Artificial Neural Network for an accidental appraisal expert system. Two Artificial Neural Networks case-based and party-based are developed. Two ANN models are trained and validated by a cross-validation model. The network achieve a goodness score of 85.72% in training and 79.1% in validation. General Influence (GI) index is used to measure the importance of each variable. Neural networks with back-propagation algorithms are used. Artificial Neural Network performs better than the DA model. ANN 2 model showed more accuracy in both training and validation than ANN1.

Rani et al., [14] developed Artificial Neural Networks for forecasting the engineering properties of soil. A network with various layers with feed-forward backpropagation is used. 68 soil test data was collected from the laboratory. 47 data use for training and 27 soil data for testing. From developed architecture 5-5-4, 5-6-4, 5-7-4 and 5-8-4 (input-hidden layer-output), the architecture5-8-4 found satisfactory. A graph is plotted between predicted values and observed values. All points in the graph are found close to the equality line.

Atalla and Hegazy, [15] identified the factors which affect cost performance of reconstruction project. A questionnaire survey is used to identify the factors related to cost performance. A cost performance index is employed to scale the cost work of the surveyed project. Statistical analysis is performed on collected questionnaire data. 18 significant variables are identified. To forecast the cost performance of the reconstruction project two models are identified. CPI values identified by both models are identified to be correlated. ANN found it suitable to detect any pattern found in data. ANN found suitable for the problem include high uncertainty and when statistical analysis not practical.

Melia et al., [16] performed a analysis on safety climate and discuss the risks that can occur in the construction industry. The series of safety components is analyzed among safety responses. Two samples are obtained in Spain and England. Safety response of organisations and Supervisors Response on safety found related in construction sample.

Kurd et al., [17] outline the safety criteria for the behavior of the neural network. Hybrid Artificial Neural Network is presented. The safety lifecycle for Artificial Neural Network is also presented. The lifecycle provided accepted forms of safety assurance. Managing behavior by Artificial Neural network also represent under lifecycle. Neural networks can work in an unpredictable and changing environment. The use of hybrid Artificial Neural Networks as highly-dependable roles in safety-critical systems is found as a potential in safety.

Seo et al., [18] analyze the safety behavior of workers by structural equation modeling. The relationship between organizational and individual factors is established using SEM. The reason and connection between dependent and independent variables is established by structural equation modeling (SEM). A questionnaire survey is used to collect information from workers. Job stress has both indirect and direct effects.

Yap and Lee, [19] analyzed the factors which affect safety performances in buildings. In this study measures for improving construction workers' safety are evaluated. A questionnaire survey is prepared to collect data for factors affecting safety. PPE, equipment maintenance, attitude, and working environment were found as primary issues. Factor analysis is performed which then identified the eight most harmful factors.

Nabi et al., [20] presented a system dynamic model which simulates the factors affecting safety behavior for workers on site. Using literature review level of safety work on site are cognize. Cellular automation is introduced. Dependency under the environmental and managerial category is found under the model. A hypothetical project is used for testing model results.

Usukhbayar and Choi, [21] conducted a investigation on safety elements influencing the safety performances of projects in magnolia. Various safety factors are identified using literature involving specific construction projects. A RII method is used to categorized safety factors. The T-test is used to evaluate the difference between risk factors categories. Not wearing PPE is identified as a major risk factor among 58 risk factors. 13 safety group factors are identified by factor analysis. A reliability test is conducted to access stability in collected data.

Yap et al., [23] performed an analysis on rework causation which focuses on safety production during construction. 20 causes creating rework that create a problem were highlighted from the previous studies. The questionnaire was used to gather information from various professionals. Rework causes are ranked based on frequency and severity values. Spearman's rank correlation is used. Five factors that create rework were identified using exploratory factor analysis.

Shen et al., [24] developed a safety indicating model on the basis of an optimized BP algorithm for building construction. Top six most important factors were identified. For security incidents, four factors were analyzed. Model is validated by multiparty consultation and by empirical analysis. The model has the prediction ability of risks during the construction phase.

Singh et al., [25] proposed a deep neural network model which can predict road accidents. Accident data were collected of eight highways from official records. From 222 data of accident 148 is used for training and rest 74 samples are used for purpose of testing. Random effect negative binomial and gene expression programming models were used to compare the predicting performances of DNN based model.

Sun and Huang., [26] presented a prediction model based upon optimized backpropagation neural network and a secondary decomposition algorithm. A secondary decomposition algorithm is incorporated into price forecasting. The case study is used to validate the model. By using partial autocorrelation analysis model input was determined. The mean absolute percentage error found out to be 1.7577% and goodness of fit comes out to be 0.9929. The root mean square error of the model comes out to be 0.5441.

Kannaiyan et al., [27] conducted a study on artificial neural network techniques and RSM. Both techniques are compared. The artificial neural network is found to be best in fitting to compute output. The artificial neural network has higher modeling abilities. The coefficient of model determination which is R2 is found close to unity for both Artificial neural network and RSM.

2.2 Summary of Literature Review

Based on these literature reviews we came to the following conclusions:

- Various factors affecting safety at construction site found in each study and each risk factor are categorized according to their responsible group.
- Different numbers of safety factors affecting safety were found in each study. A respondent's self-report safety behavior was used by many researchers to know about their performance on site.
- In some cases Neural Networks model is used for training and validating data. Multilayer feedforward neural networks were used with a different number of hidden Neurons.
- Neural Networks can be used for prediction and also for ranking of any data and it provide better solutions than conventional regression approaches. Neural network methodology can easily handle ill-structured data.
- Overfitting ratio (OR), Sensitivity Analysis, Mean absolute percentage deviation, and Absolute percentage deviation can be applied to check the validations of the model.
- Findings demonstrate that giving scores for self safety is a good approach when time and monetary resources are restricted.
- Effects of Unsafe behavior were identified as: (1) Loss of life (2) Cost overrun (3) Time overrun (4) Fatal accidents (5) Litigations.
- Risk at each construction site vary according to nature of project and based on it safety measures adopted so that higher safety can be achieve at site.

2.3 Objectives

Depending upon the literature, the following objectives are defined:

1) To evaluate and identify factors affecting safety of infrastructure projects.
2) To develop a Neural Network model that can predict a safe work environment at the construction site.
3) To suggest guidelines to improve safety at the construction site.

2.4 Scope of the Study

This study will help project team to achieve higher safety at site and can help in reducing accidents at construction site. This study developed a Neural Network Model which will be used to predict a safe work environment at the construction project site. Identifying factors which affect safety before starting of work will help in reducing risk. This study recognizes the top factors group which are involved in affecting safety related practices and can help the construction team to lift up safety at the project site before the start of work. Remedial measures are also suggested to enhance safety at the infrastructure project site.

CHAPTER 3

METHODOLOGY

3.1 General

In this the research work is done in different phases. The process of research is shown by Fig. 3.1.

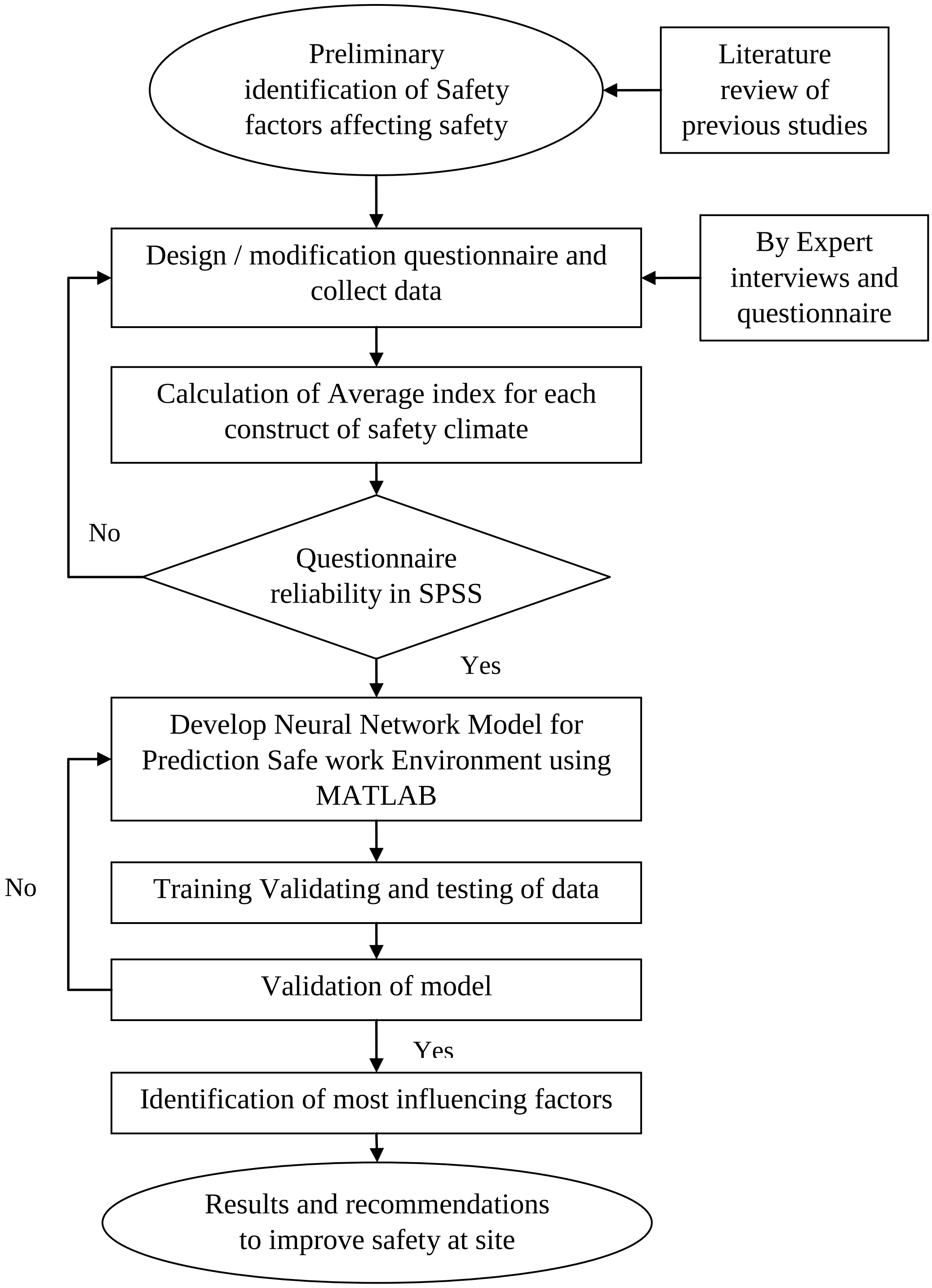


Figure 3.1 Research Framework for improving safety at site

The prime purpose of this research is to constitute a model for predicting a safe work environment at construction projects site. It is not easy to get data from various infrastructure projects due to time practical constraints. The following sections describe the process of research work.

3.2 Selection of Variable

In this analysis firstly safety climate constructs were determined from the literature review. Different factors affecting safety at the construction site are determined. Providing a safe environment, provision of safety booklet, provision of safety equipment was the safety factors associated with site safety. Employee's behavior, work pressure by the organization, management Commitment, providing support during work, Management communication, supervisory environment and employee involvement were the different factors affecting safety climate found from the previous studies conducted. The safety components affecting safety structure are then put as input values for the development of the Artificial Neural Network. After the determination of safety climate factors/constructs, the next step is to prepare a questionnaire to get an opinion from site employees about the site safety.

3.3 Questionnaire structure

The need of questionnaire is to gather knowledge about factor affecting safety of construction site. The questionnaire is made from factors developd and identified in this study. First part of questionnaire is shown in Table 3.1. whole questionnaire is shown in the Appendix-A.

Table 3.1 General information of Company and Respondent

Section I: Company / Department Profile	
1.Company Name:	
2.Contact No (Optional):	
3.Nature of Company:	Client ☐ Contractor ☐ Designer ☐ Consultant ☐
	Other (Please Specify)...................
4.Age of the Company: (years)	1-5 ☐ 6-10 ☐ 10-15 ☐
	More Than 15 Years ☐
Section II: Respondent Profile	
1.Name (Optional):	
2.Position in the Company:	Site Supervisor ☐ Engineer ☐ Site Manager ☐
	Any other (Please specify)...................
3.Experience in the Construction Industry:	
	1-2 Y ☐ 3-4 Y ☐ 5-6 Y ☐ 7-10 Years ☐
	10 Years and above ☐

3.4 Questionnaire survey

A questionnaire is prepared based on the safety climate constructs found from the literature review and from expert opinions to know the level of agreement about the safety factors and employees performance on site. The questionnaire was then distributed among various professionals and workers at the construction site. The target respondents were Site supervisor, Site Engineers, Labours, and Site Manager. The questionnaire was provided with the variable to rank factors/statements based on their knowledge. Five-point Likert from totally disagree to strongly agree scale is adopted. The questionnaire was distributed to various construction companies to know the viewpoint of safety at the construction site.

At construction site judgeing the behavior of employees is not easy in limited visits. So reporting self safety method is choosed in this research. Occasionally questionnaire which are self-reported can be double-faced. If these samples are together, then they will show a real status of safety than organization structure. This method of self-reporting is more reliable in behavior sampling. Therefore, reporting self safety behavior method is considered for this research.

The questionnaire consists of three phases. The first phase is designed to get the personal information of the respondent. The second part consists of safety climate constructs and their attributes. In the third phase, empoless were asked to give scores to themselves for safety rules they follow on site between a scale of 0-100%. Interviews among workers were also organized to get more knowledge about safety. More than one response from a project is obtained so that the stability of respondent's understanding of the safety structure is maintained. The respondents approached construction sites and suitable responses collected from them.

3.5 Average Index Analysis

After collecting data from the questionnaire, the next step is to calculate the Average value for each factor. In this equal weight for each attribute/factor is assigned. A dimensionless quantity, Average Index is calculated which represents the value of safety group. The formula of the Average index is given by Equation 1.

$$AI_{\mathrm{m}} = \frac{1}{3}\sum_{n=1}^{3} A_{\mathrm{mn}} \tag{1}$$

Where AI_m= Average index value of mth group, where m= 1 to 10.

A_{mn}= Weightage given to nth factor of each risk group (ranges from -1 to 1)

Where n= 1,2,3.

For linguistic terms assigned values are shown in Table 3.2.

Table 3.2 Scale for questionnaire

Strongly Disagree	-1
Disagree	-0.5
Neither disagree nor agree	0
Agree	0.50
Strongly Agree	1

The range of AI is between -1 and +1 and AI values will used as input values for model. Safe work behaviour of employee is used as output for the model.

3.6 Development of ANN

The relationship between input values and output values is unassured, unclear and due to subjective judgment data was a noisy causing error. In most cases between input and output linear relations can't occur. ANN is a model formed from artificial neurons, connected with links and these links has a weight that makes the neural structure. Fig 3.2 showing the architecture of ANN.

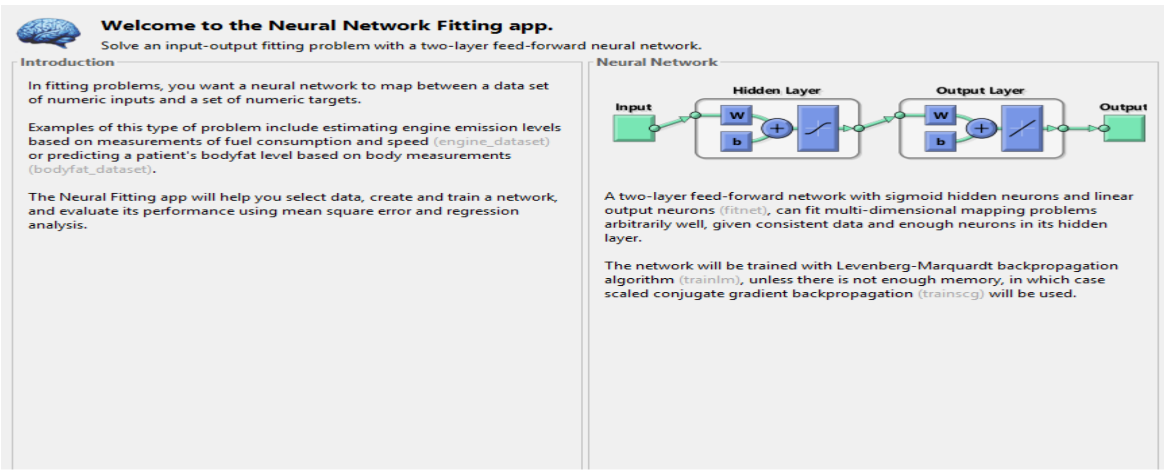


Figure 3.2 Introduction to Neural network

Step 1: Architecture of Artificial Neural Network

Three training algorithms have been used to train a network named as Levenberg-Marquardt, Bayesian Regularisation, and scaled conjugate gradient. These three algorithms used one by one for training a network to find which algorithm would be best for the network. Moreover, network with backpropagation is good for solving non-linear computations and its process continues until the desired result does not come. Backpropagation is slow for convergence and can create overfitting problems. Levenberg-Marquardt can overcome this overfitting problem because it gives very little MSE than other algorithms.

In this paper, a feed-forward backpropagation network is used. The Neural Network is developed using MATLAB. Moreover, Levenberg-Marquardt back-propagation (trainlm) Bayesian Regularisation (trainbr), and scaled conjugate gradient (trainscg) was used for training and the logsig acted as the activated function for Artificial Neural Network. First one hidden layer is selected for the network and by performing trials the number of neurons are decided.

Step 2: Training, Validation and testing process

For developing model training require several trials starting from varying neurons to checking mean square error. The neurons in hidden layer are selected depending upon on Mean Square error of Artificial Neural Network. As by increasing neurons mean square error should not increase. The learning parameter and variation of the cycle should vary until the RMSE error is reduced. Value of regression is checked for the three training algorithm and the Training algorithm which will give best results for the regression value will be use for the development of model.

3.7 Reliability Test

To check the reliability of responses Reliability test is performed in SPSS. In SPSS Cronbach’s Alpha test is performed to check the reliability of our responses. Value of Cronbach’s coefficient range from 0 to 1. A coefficient value closer to 1 indicates that data is reliable. If the value comes greater than 0.6 then data is said to be reliable.

3.8 Model Validation

The validations of the developed model are done by using Mean Absolute percentage Error. It is considered to validate the forecasting accuracy of the model. The formula which is used to calculate Mean Absolute Percentage Error is given in Equation 2.

$$M = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - A_e}{A_t}\right| \qquad (2)$$

Where A_t= Actual value.

A_e= predicted value.

N= Number of values.

3.9 Factor analysis

Factor analysis is performed to simplify data and reduce the number of factors/variables. 30 risks affecting safety structure were identified in this research and classified into 10 groups. Factor analysis is performed on 10 safety factor groups.

First for checking the adequacy of data Kaiser-Meyer- Olkin (KMO) test is performed. In KMO test by measuring the variance among the different variables partial correlation is measured. KMO values very between 0 and 1. For interpreting statics values of Kaiser-Meyer-Olkin is shown in Table 3.3.

Table 3.3 KMO values for factor analysis

KMO value	**Consideration for factor analysis**
0.0 to 0.49	Inadmissible
0.50 to 0.59	miserable
0.60 to 0.69	medium
0.70 to 0.79	middling
0.80 to 0.89	Admissible
0.90 to 1.00	Remarkable

KMO value greater than 0.5 indicates that data is adequate for performing factor analysis. If KMO value comes out less than 0.5 there is sample issue. **Bartlett's test of sphericity** was also performed in which reliable correlation was assumed. In Bartlett's test assuming significance level 95% and $\alpha = 0.05$.

Components with eigen value greater than or equal to 1.0 were consider for factor analysis. Parallel analysis was performed on 10 variables, 282 respondents, and 100 replications using Monte-Carlo PCA parallel analysis.

CHAPTER 4

ANALYSIS

4.1 General

Various safety climate factors which affect safety at the construction site were identified by literature review and from expert's opinion. The different safety climate factors which affect safety are then categorized according to their responsible groups like Regulatory group, Workload group, Co-Management group, Awareness group, Encouraging group, Safety Management Group, Equipment group, Conveying group, Ability group, and Protection group. After categorizing risk factors the questionnaire is prepared and distributed among various employees and workers. 308 responses were received from various companies and 282 were selected for data analysis and development of Artificial Neural Network. The company's profile includes 7% respondents work as a client, 78% as a contractor and 15% were as Designer. The profile of respondents who responds to questionnaire are shown by a pie chart given in Fig. 4.1.

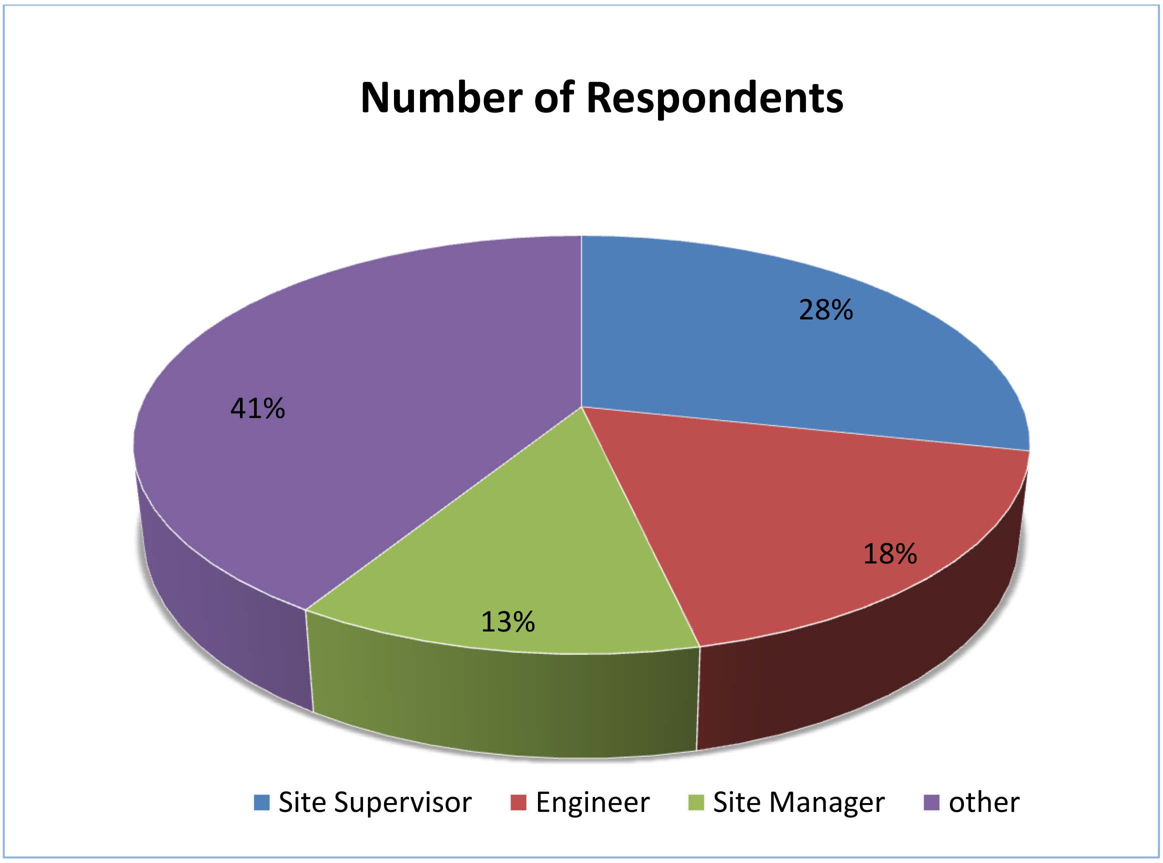


Figure 4.1 Respondents participated in questionnaire survey

282 Respondents with their different experience in the construction company as shown in the fig. 4.2. Based on their level of aggrement about facor data is collected.

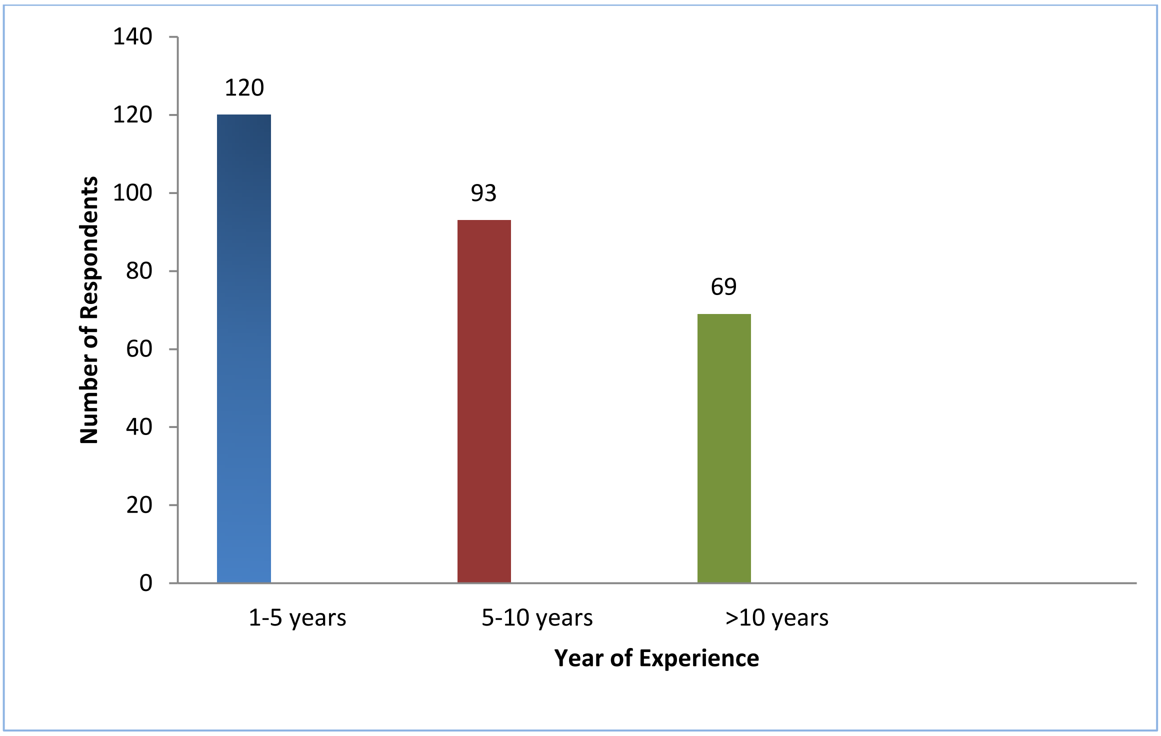


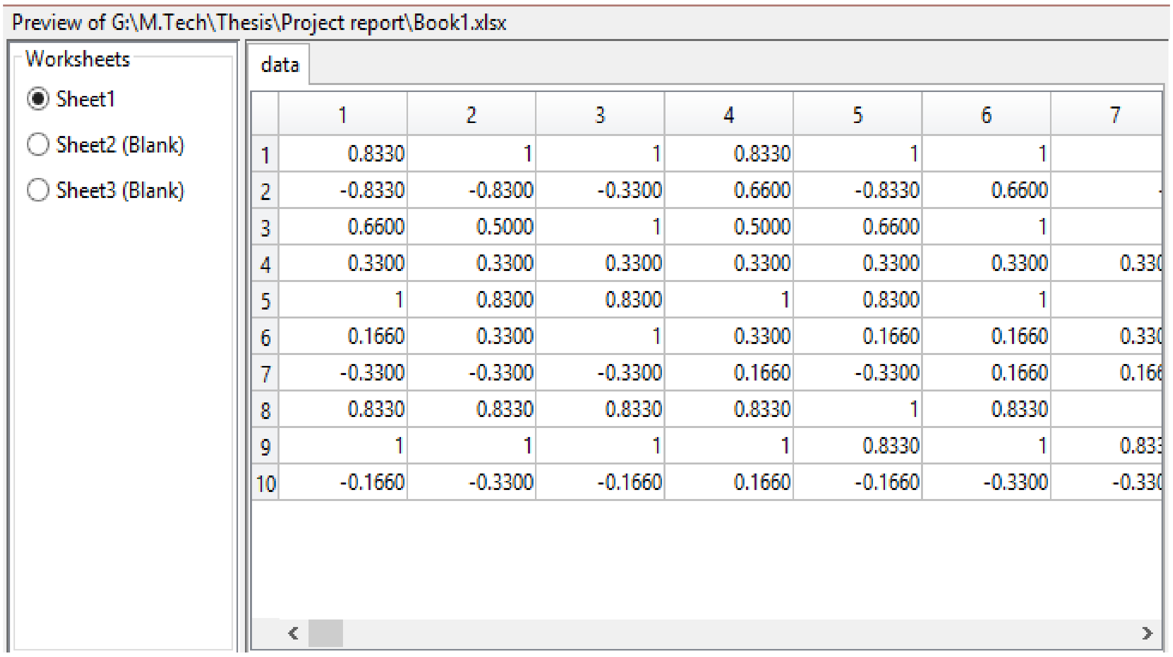
Figure 4.2 Respondents year of experience in construction industry

The company profile and different age group of respondents are shown in Table 4.1.

Table 4.1 Company profile and age groups of respondents

S. No	Variable	Category	Frequency	Percentage%
1	Company profile	Client	19	7%
		Contractor	222	78%
		Designer	42	15%
4	Age group	21-30	58	20%
		31-40	93	34%
		41-50	69	24%
		>50	62	22%

The respondents were asked to give importance to factors affecting safety at the construction site. A Likert scale of -1 to 1 is used to give importance to delay causes. After collecting data the next step is to calculate the Average index for each factor affecting safety. The calculated values of the Average index for various factors are given in Appendix- C. Fig. 4.3 showing the worksheet of input values of ANN.


Preview of G:\M.Tech\Thesis\Project report\Book1.xlsx

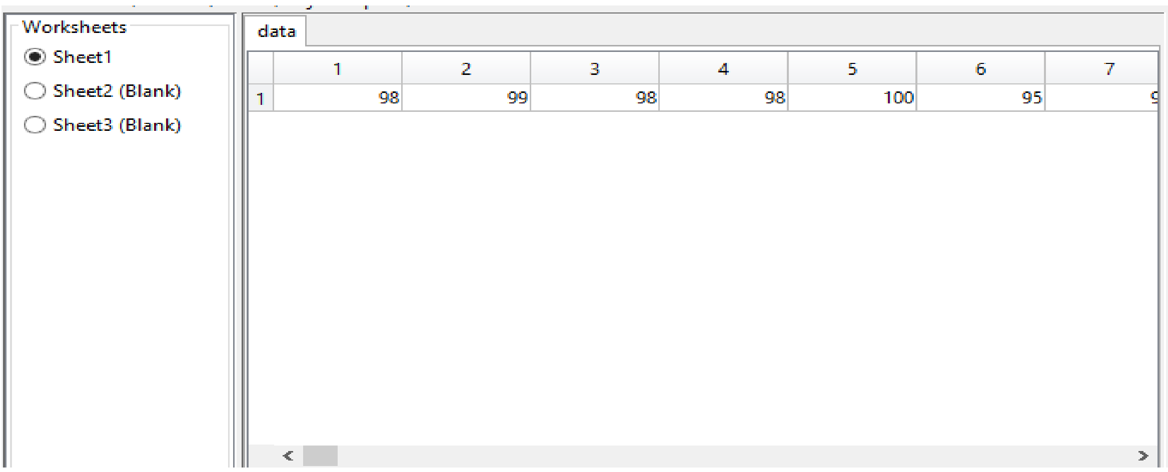
Worksheets
Sheet1
Sheet2 (Blank)
Sheet3 (Blank)

data

	1	2	3	4	5	6	7
1	0.8330	1	1	0.8330	1	1	
2	-0.8330	-0.8300	-0.3300	0.6600	-0.8330	0.6600	-
3	0.6600	0.5000	1	0.5000	0.6600	1	
4	0.3300	0.3300	0.3300	0.3300	0.3300	0.3300	0.330
5	1	0.8300	0.8300	1	0.8300	1	
6	0.1660	0.3300	1	0.3300	0.1660	0.1660	0.330
7	-0.3300	-0.3300	-0.3300	0.1660	-0.3300	0.1660	0.166
8	0.8330	0.8330	0.8330	0.8330	1	0.8330	
9	1	1	1	1	0.8330	1	0.833
10	-0.1660	-0.3300	-0.1660	0.1660	-0.1660	-0.3300	-0.330

Figure 4.3 Input values for Neural Network Model

The values of Average index are then entered in the model as an input for the Neural Network Model and these values come in a worksheet in the form of a matrix. The input data can be changed in the worksheet of MATLAB. The input values in MATLAB are entered in the form of a matrix of 10x252, which shows that 10 are the safety climate factors affecting safety and 252 are the values of the calculated Average index.


Worksheets
Sheet1
Sheet2 (Blank)
Sheet3 (Blank)

data

	1	2	3	4	5	6	7
1	98	99	98	98	100	95	9

Figure 4.4 Target values for ANN Model

The self reported safety at site indicated by employees is used as a target value for the model and is shown in Fig 4.3 Fig 4.4 showing the selected data for input and target values. The selected input representing the static data of 252 samples of 10 elements and targets data representing statics data of 252 samples of 1 element.

4.2 Network Design

After getting the input and output values from the questionnaire survey neural network is designed.

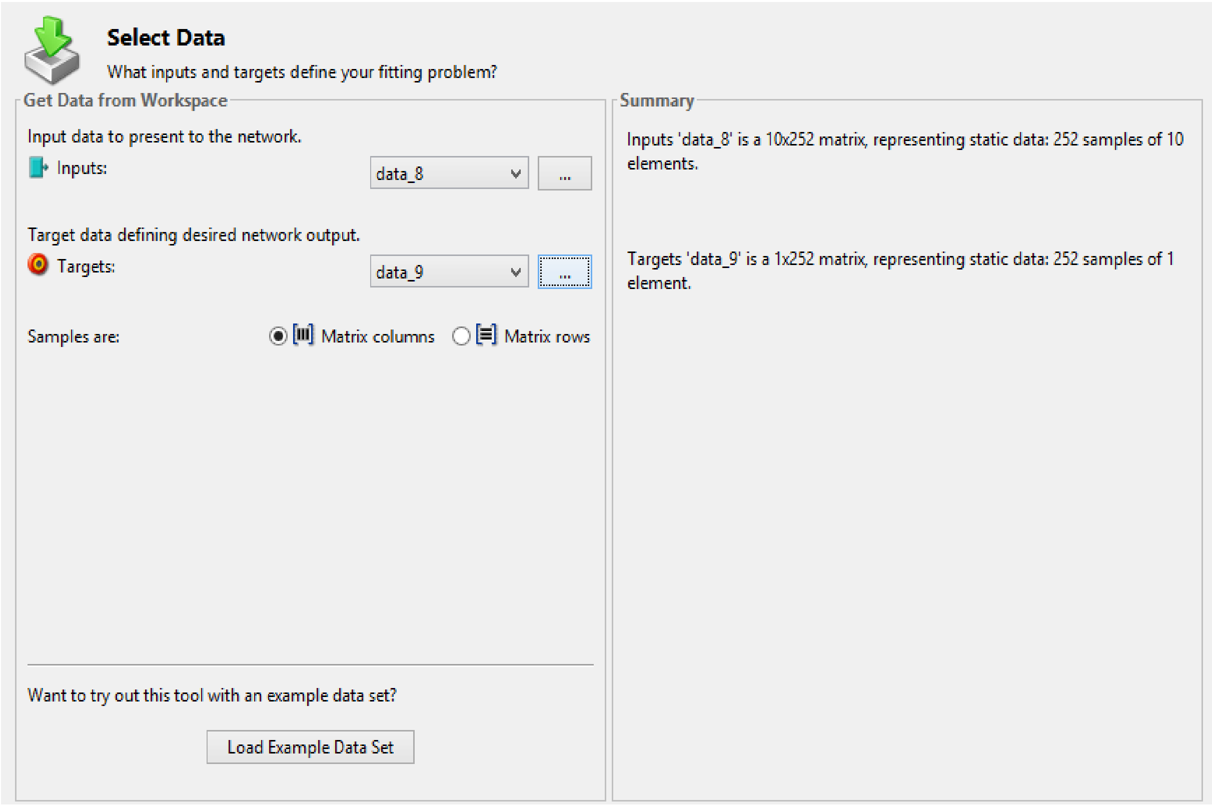


Figure 4.5 Input- Target values from workspace

After adding input and target values for the model the samples are randomly divided for further three phases.

4.3 Training Phase

In the Training, Validating, and Testing process data is divided according to the percentage. Fig. 4.6 showing the samples divided for the Training, Validation, and Testing phase. From 252 samples 60% samples ie. 152 are used for training, 20% samples ie. 50 are used for validation and 20% samples (50) is used for testing purpose.

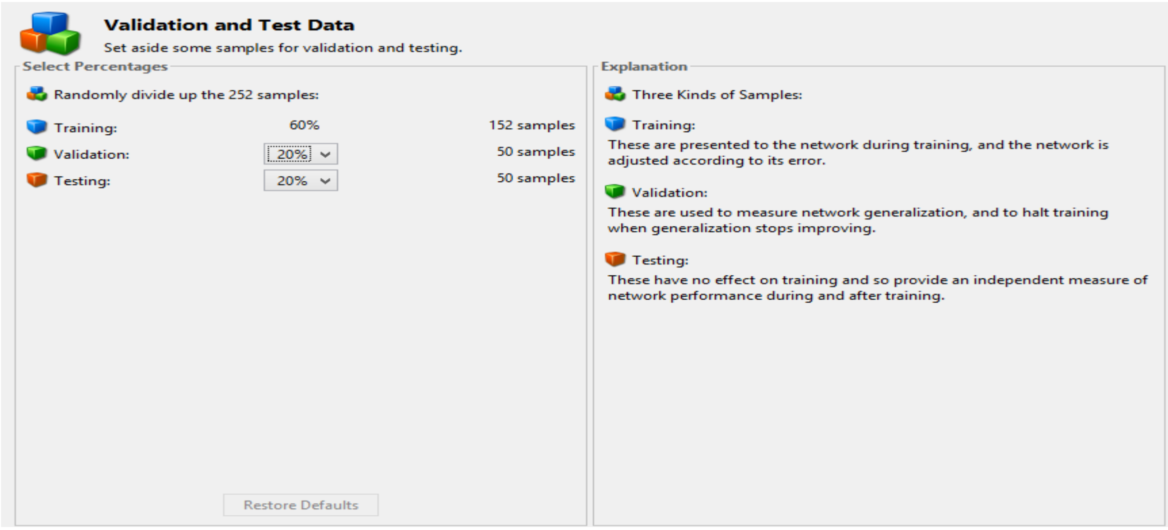


Figure 4.6 Test data distribution process

After dividing samples into 3 processes Number of Hidden Neurons are selected. The number of Neurons can be varied if the network does not perform well during the training process. Various trials have been done and the number of Neurons is varied. Fig. 4.7 showing the selection process of the Number of hidden neurons. These neurons are varied until the regression value comes closer to one. Different trials have been done for performing well network during training. If the network does not perform well then again return to the network architecture part of ANN and then again test the model for the testing. Number of hidden neurons are varied for three algorithms so that best training algorithm can be choosed for the network. After getting the coefficient of correlation value closer to unity, the tested architecture of ANN will be selected for the model.

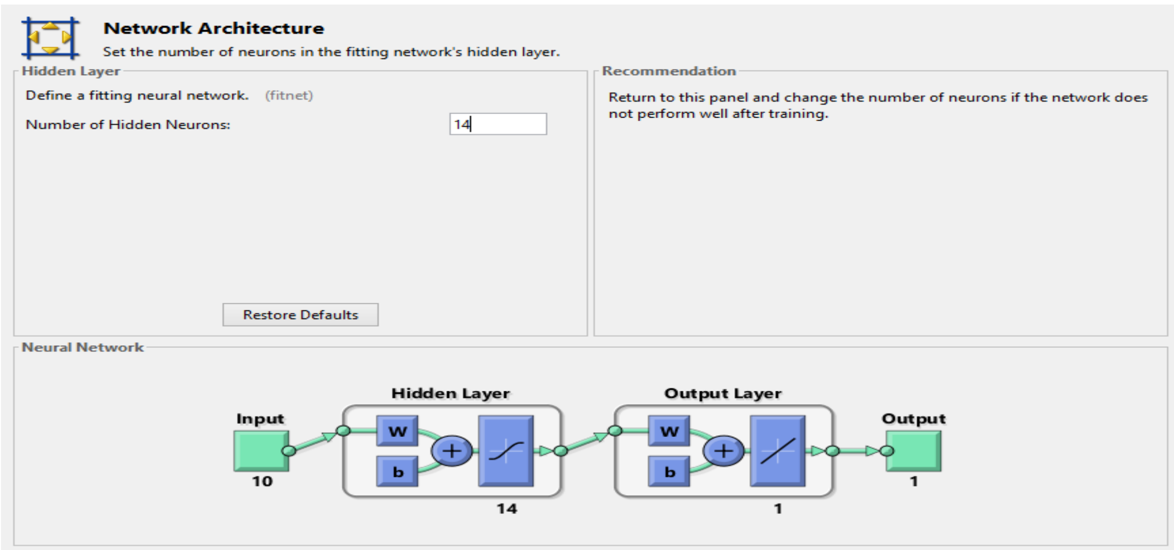


Figure 4.7 Hidden Neurons selection

4.4 Comparisions of Training Algorithm

Three training algorithms has been used so that best would be selected. Different number of hidden Neurons are varied on each training algorithm and comparision of three training algorithm is given in Table 4.2.

Table 4.2 Predicting performance of different training algorithms

Activation Function	**Training Algorithm**	**Neurons in hidden layer**	**MSE**			**AII: R**
			Training	**Validation**	**Testing**	
TANSIG	Levenberg-Marquardt	11	0.008	0.014	0.013	0.934
		12	0.017	0.101	0.021	0.951
		14	0.006	0.019	0.016	0.977
	Bayesian Regularisation	12	0.012	0.017	0.136	0.894
		14	0.006	0.019	0.012	0.965
		16	0.019	0.016	0.028	0.912
	Scaled conjugate gradient	10	0.013	0.019	0.015	0.814
		12	0.217	0.033	0.021	0.905
		14	0.031	0.019	0.013	0.928

Levenberg-Marquardt is used as a training algorithm because this algorithm requires less time rather than Scaled Conjugate Gradient and Bayesian Regularization. Levenberg-Marquardt requires low mean square error than other training algorithms. Training is done multiple times until the mean square error value reaches a minimum and the coefficient of correlation value comes closer to unity. Training algorithm is selected based on the COC value and mean square error values.

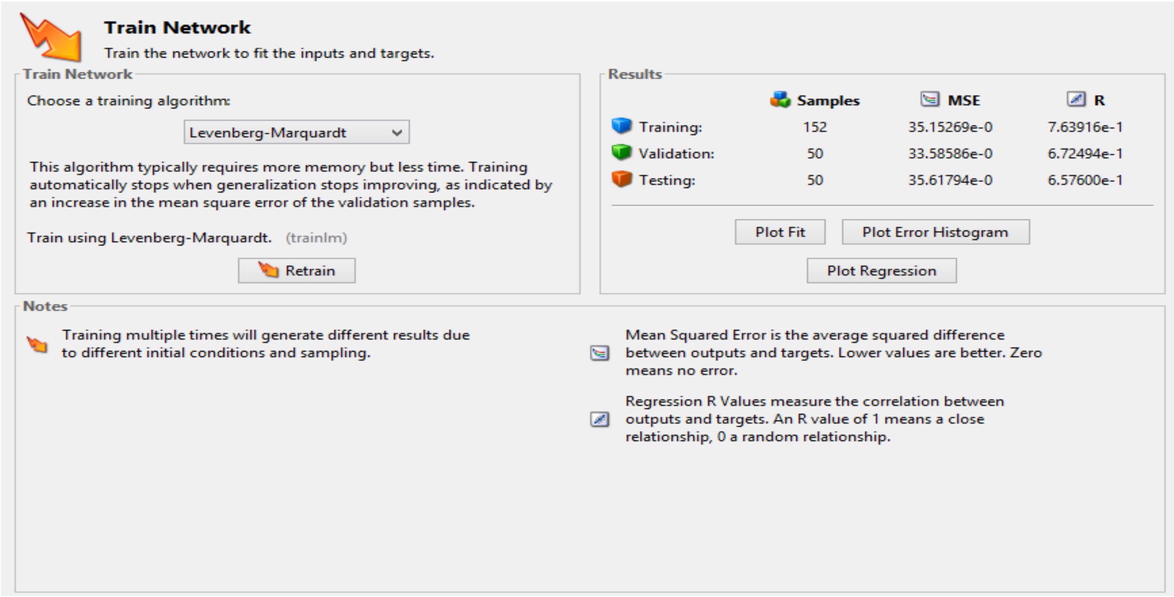


Figure 4.8 Training of Network

14 numbers of hidden neurons are found satisfactory for the network by performing various trials. The developed Regression chart for Artificial Neural Network is shown in Fig.4.9.

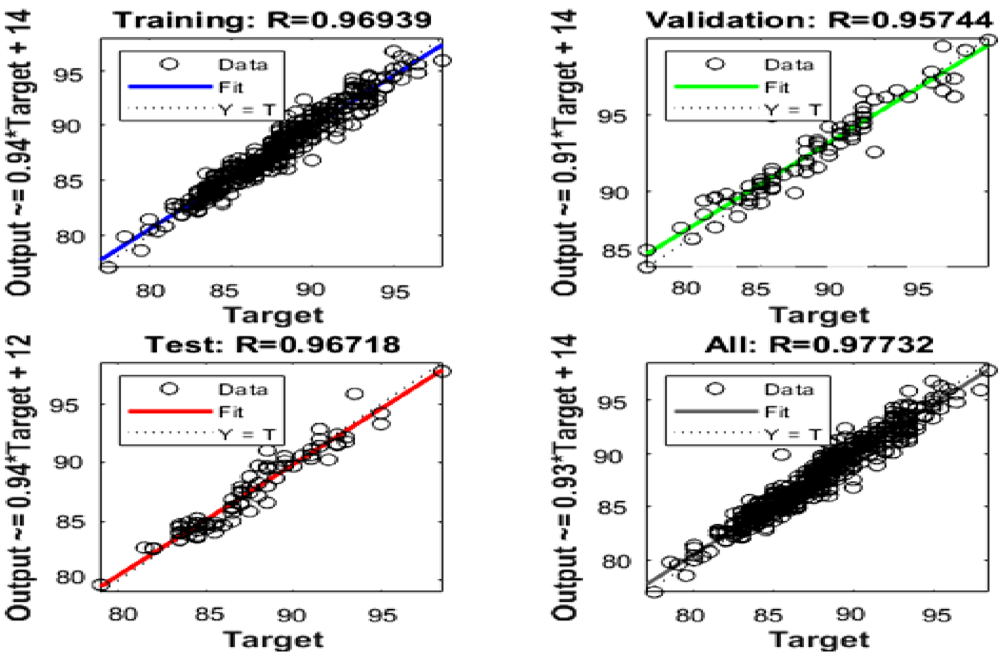


Figure 4.9 Regression plot for training, validation and testing process.

The Hidden layer of 14 Neurons is found satisfactory for the model and Network 10-14-1 is found satisfactory for Artificial Neural Network Model. Where 10 represents the number of the input parameter, 14 represents the Number of Hidden Neurons and 1 represents the output parameter.

The regression chart for 14 number of neurons is plotted in model and is shown in fig. 4.9 which shows that Coefficient of Correlation values (R) is greater than 0.9, which imply a positive linear connection between output and target data. Coefficient of Correlation value of 0.97732 and MSE of 0.008 for training process proves that the selected network has fewer errors and can be used for predicting safety practices at the site.

4.5 Mean Absolute Percentage Error (MAPE)

Mean Absolute Percentage Error is a process to validate the forecasting precision of the model. MAPE is also called as Mean Absolute Percentage Deviation. It is the most commonly used term for validating the prediction of any developed model. Mean absolute Percentage Error is calculated for the predicted data and actual collected data. The formula for absolute values of errors divided by the actual values is given in Equation 3 and represented by $A_{p.}$

$$A_P = \left|\frac{A_t - A_e}{A_t}\right| \tag{3}$$

Where A_t= Actual value.

A_e= predicted value.

Fig 4.8 showing the data management tool by which the samples can be checked. The values of input and target data are then added from the workspace and then the network can be select. These data sets are then trained after selecting the network and according to the training and learning functions datasets output can be predicted.

After selecting the parameters, the neural network is trained under the developed architecture of ANN i.e 10-14-1. Fig 4.11 showing the network training information for testing of data. After selecting the input and target data the network is trained and output will be predicted and can be compared with the actual values of the samples. If the training results did not come satisfactory then training parameters can be changed and then results will come as per the requirements.

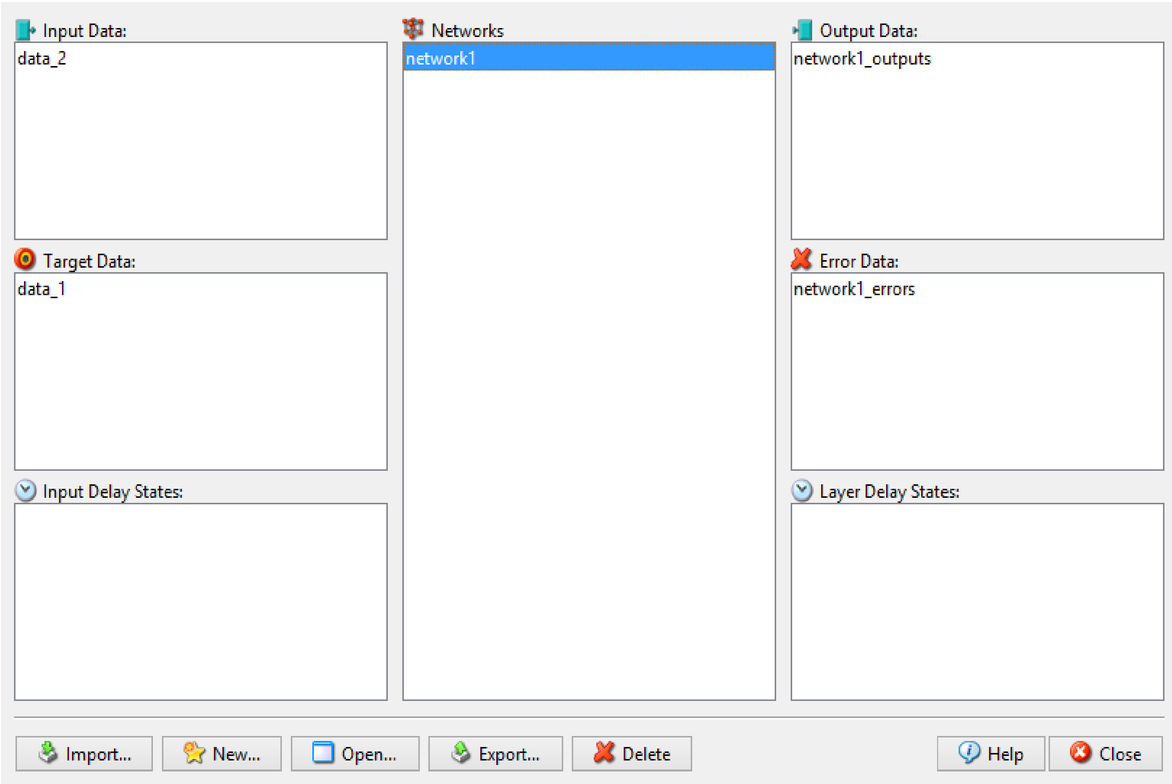


Figure 4.10 Neural Network Data Manager

Training algorithms and network types can be changed for getting satisfactory results. Moreover, weights are also adjusted in the view/Edit weights section of the neural network.

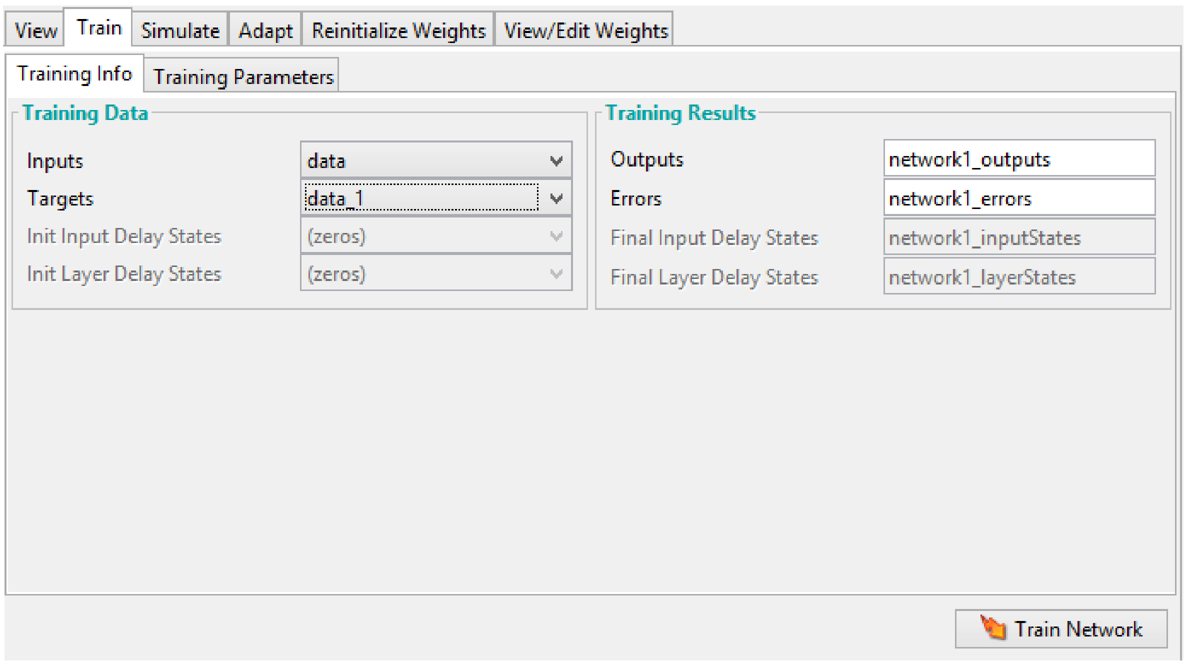


Figure 4.11 Network Data Training Information

Fig. 4.12 showing the predicted values for output from MATLAB output section.

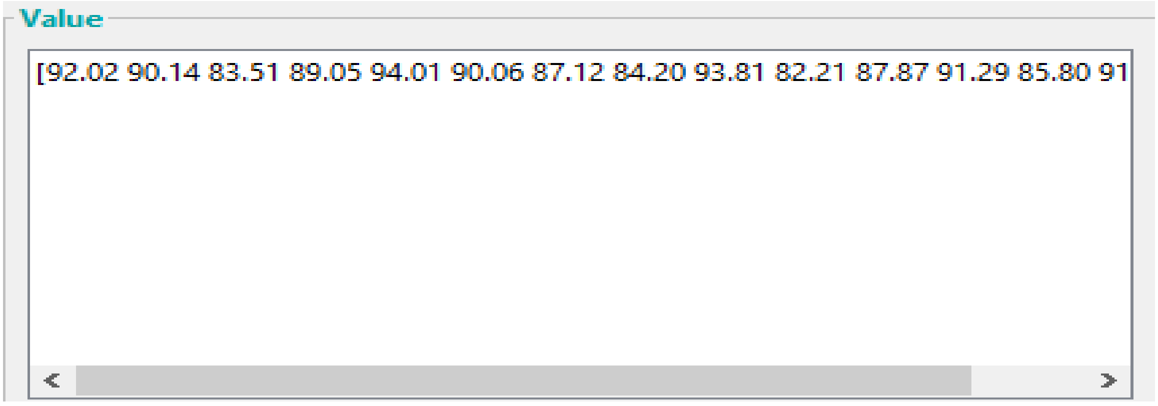


Figure 4.12 Output values for validation samples

For validating model these above values are compared with the actual values. MAPE is calculated for 32 samples. The formula for calculating the value of MAPE is given in Equation 2. The calculated values of MAPE for the 32 samples are shown in the results section.

4.6 Factor Analysis

Factor analysis was performed on 10 factors group. In our KMO test value of 0.759 was found which indicates that samples are adequate for performing factor analysis. Four components were found to have value of eigen more than or equal to one.

From four components those values are selected for creating factors whose value comes greater than random eigen value from parallel analysis. Three components found to be valid according to monte carlo parallel analysis. Factors affecting safety divided into three groups according to factor analysis. Related component matrix for the components is given in Table 4.3.

Table 4.3 Related component matrix for three groups

Group	**Critical risk factors**
Group 1	F1, F3, F10, F5
Group 2	F2, F9, F6, F4
Group 3	F7,F8

CHAPTER 5
RESULTS AND DISCUSSION

5.1 General

Systematic management can improve safety performances which can lead to minimizations of risks hazard. The questionnaire survey was used to collect data. Out of 308 responses 282 responses were considered for the analysis. 252 responses were used for the development of ANN and the rest 32 were used for the validation process. MAPE is used for the calculations of errors between the predicted and actual values.

5.2 Safety factors affecting safety

In this research different factors affecting safety were identified by detailed literature review and also from expert opinions. Average index is calculated for each factor affecting safety at the worksite is shown in Appendix-C. Where in Appendix-C 1, 2, 3, .., 282 represent the responses, and F1, F2, .., F10 represents the safety climate factors affecting safety at work site. 10 safety climate factors group identify in this study as shown in Table 4.1.

Table 5.1. Group categorization affecting safety used in this Study.

Factor Number	Safety Climate constructs/Factors
F1	Regulatory group
F2	Work load group
F3	Co Management group
F4	Awareness group
F5	Encouraging group
F6	Safety Management group

F7	Equipment group
F8	Conveying group
F9	Ability group
F10	Protection group

Based on different factors affecting safety at the construction site questionnaire is made and distributed to the experts who had a good experience in safety. Out 308 data 282 were considered who represent Site supervisors, Engineers, site managers, and laborers, etc. Average index values are calculated by using the formula given in equation 1 and safe work behavior according to their level of agreement is shown in Figure 4.2 in the matrix of 1x252. The average index used as input values for the model and safe work behavior as target values/output for Neural Network Model.

5.3 Reliability Analysis

A reliability test was performed to check the consistency of data. SPSS (Statistical Package for Social Science) is employed for performing the test. The value of Cronbach's alpha coefficient obtained from Statistical Package for Social Science is 0.72 which is greater than 0.6, which shows that our data is reliable.

5.4 Network Training

Out of 282 samples, 252 samples are used for giving input-output values in the model. 60% samples are employed for training. 20% i.e. 50 samples are employed for the validation process, and the rest 20% samples are used for the testing process. Training is performed on three different algorithms and algorithm which give regression value close to one is selected for the network. For training purposes, the Levenberg-Marquardt algorithm is selected because it requires low MSE (Mean square error) and it used less time in the training process as compare to other training algorithms. The training process continues until the coefficient of correlation value comes closer to unity as compare to other varying hidden neurons. 14 hidden neurons are found satisfactory for the artificial neural network after performing various trials. The MSE value for 14 number of hidden neurons comes out to be 0.008 for training and and Coefficient of Correlation value of 0.9773.

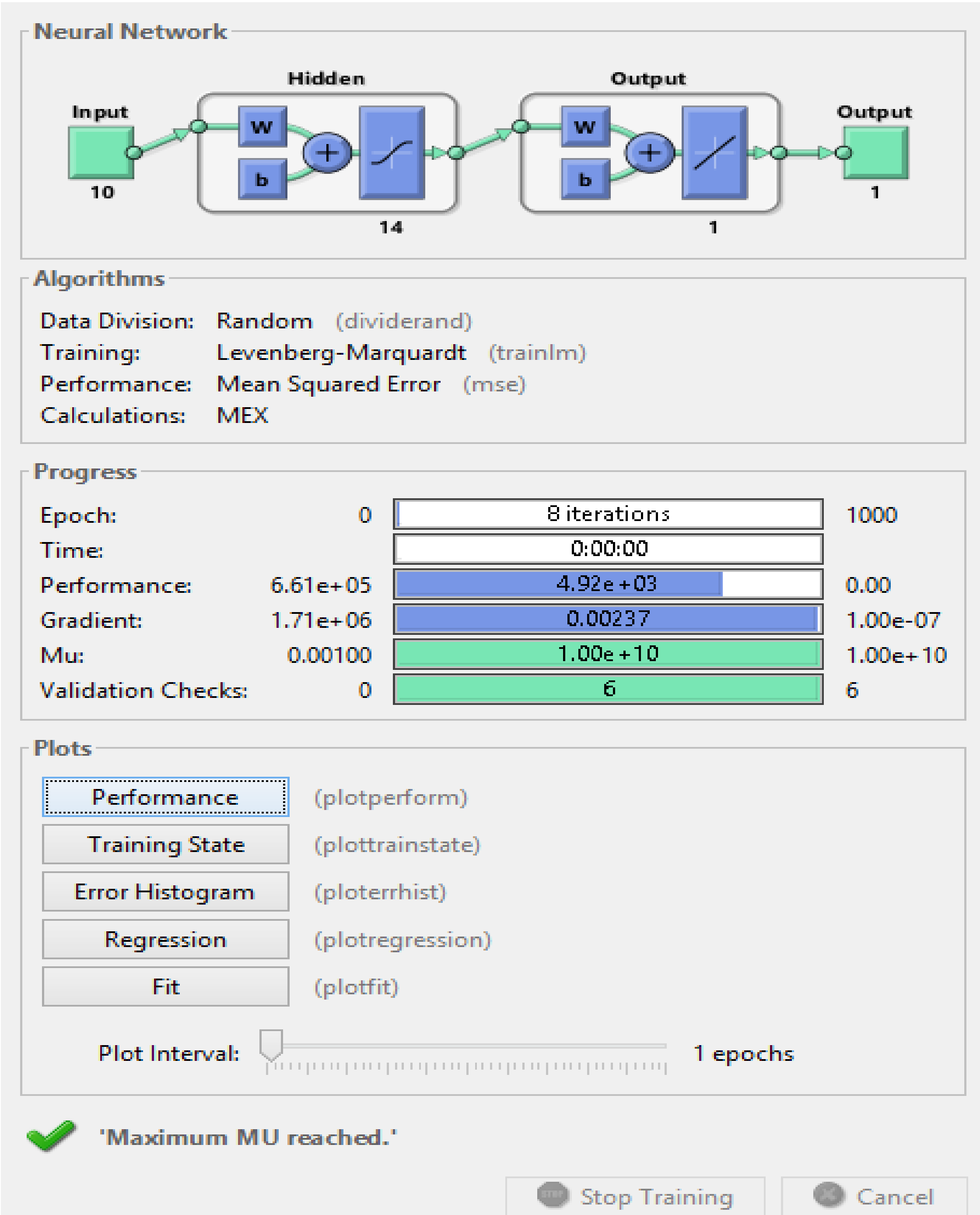


Figure 5.1 Network training with ANN

Fig. 5.1 showing the Training process of ANN. Network 10-14-1 provides the least value of error as comparision to trials on various hidden neurons. So the developed network 10-14-1 will be used for artificial neural network prediction. In Fig 4.9 Coefficient of Correlation value is greater than 0.9, which is very close to target and output values. The regression line showing the relationship between both variables ie. The target and output value is very close to 1 which results in a positive linear relationship. Feed-forward backpropagation is used as a network type rather than other networks type like feed forward time delay etc.

32 samples that were separated from the questionnaire survey are used for validation of the model. MAPE is the ratio of difference of actual value given by the respondent and the predicted value by the model to the actual value of the model.

5.5 Mean Absolute Percentage Error

After getting the output values of 32 samples from the neural network. The values are compared with actual values. MAPE (Mean Absolute Percentage Error) is calculated for the values so that model can be validated. Table 5.2 showing the calculated values of mean absolute percentage error.

Table 5.2 Calculated Absolute value of error divided by actual values

Number of Respondents	Actual value	Predicted value	A_P
1	99	92.02	0.07
2	98	90.14	0.08
3	95	83.51	0.12
4	97	89.05	0.08
5	99	94.01	0.05
6	97	90.06	0.07
7	95	87.12	0.08
8	98	84.20	0.14
9	99	93.81	0.05
10	91	82.21	0.09

11	92	87.87	0.04
12	94	91.29	0.03
13	90	85.80	0.04
14	93	91.01	0.02
15	94	93.10	0.01
16	94	87.51	0.07
17	97	88.21	0.09
18	93	90.13	0.03
19	98	96.01	0.02
20	98	95.70	0.02
21	91	89.70	0.02
22	92	91.17	0.01
23	90	89.10	0.01
24	97	94.10	0.03
25	98	89.23	0.09
26	99	96.14	0.03
27	97	96.12	0.01
28	96	95.02	0.01
29	95	93.31	0.02
30	92	91.07	0.01

31	91	90.09	0.01
32	93	92.47	0.06

So, numbers of samples are 32. The average value of calculated absolute values of errors divided by actual values is 1.479. The value of mean absolute percentage error comes out to be 4.623%, which is under permissible range. From table 5.2 it can be seen that calculated mean absolute percentage error values come out to be very less which indicates that model is capable of predicting safe work practices.

5.6 Factor Analysis

An analysis is conducted to list the most important group influencing safety at project site. KMO test was performed and value of 0.759 was obtained which shows that samples are adequate. All the components were classify into three groups. On the basis of communalities value factors are ranked as follows:

Regulatory Group (0.968): This indicated that for achieving higher safety at construction site management should appoint a well trained safety representative on site. Safety manager and supervisor should engage in safety talks.

Equipment group (0.831): This confirms that use of advance equipment, protective clothing and experienced operator for heavy machinery are important for improving safety at workplace.

Conveying group (0.804): The result shows that providing safety information to the employees at site and organizing campaigns to promote safety are likely to reduce accidents at construction site.

Protection group (0.785): This shows the management responsibility towards employees. Good training of new employees leads to good safety awareness. Proper use of Safety equipment and protective clothing results in improving safety culture of construction site.

Safety management group (0.726): This indicates management should disciplines employees for working unsafely. Management should maintain standards toward safety and record the safety accidents at construction site so that higher level of safety can be achieved.

CHAPTER 6
CONCLUSIONS AND GUIDELINES

6.1 General

During Construction, projects face various uncertainties due to poor safety management. Poor management projects result in less productivity, accidents, loss of money, and larger project completion time. This study will help the project team to minimize reasons influence the safety of workers at the project site. Artificial Neural Network model is developed in this research which will predict that site is safe for working or not.

6.2 Conclusion

Various factors affecting safety on site were identified by literature and also from expert opinions. Ten delay groups are identified in this study and based on the responsible group statements are prepared in the form of risk. A questionnaire survey is prepared and distributed among various workers and employees who work on construction sites. This includes Site Engineers, Site supervisors, laborers, and Site Manager. Respondents were asked to responses the questions according to their level of acceptance about the statement. Total 308 responses were gathered from various sites out of which 252 were used for the development of ANN and the rest 32 samples used for the validation process. Average index is calculated for each climate factor group. Values of climate construct group are used as input values for model and safe work behavior according to their marked valued is used as the target for the neural network model. Sample is distributed in the ratio of 60%-20%-20% for training, validation, and testing process. Levenberg-Marquardt is used as a training algorithm due to its ability in fast prediction than other algorithms like Scaled Conjugate Gradient and Bayesian Regularization. Feed-forward backpropagation is used as network type. 14 Number of hidden neurons found satisfactory for Neural Network model after performing various trials in which mean square error value comes out to be 0.006 and Coefficient of Correlation value 0.977. Model architecture 10-14-1 if found satisfactory for Neural Network Model. A reliability test is performed on the collected data in which the value of Cronbach's alpha coefficient is found to be 0.72, which implies that the collected data is reliable. Model predictions are validated by MAPE (Mean Absolute Percentage Error). Value of MAPE comes out to be 4.623% which is very less. Moreover factor analysis was conducted to classify factors and to identify top most important factors. Model is found suitable for predicting safety practices at the construction site so that safety-related issues are minimized before starting any work. The project team can use this ANN(Artificial Neural Network) to reduce the unsafe safety practices at construction sites by taking a survey from employees and put them in developed ANN. Guidelines are also discussed in this study for minimizing unsafe practices at the construction site.

6.3 Mitigation Measures

In this part, theoretical and practical mitigation measures are suggested which will help management to decrease unsafe practices at the workplace. By following these guidelines management can improve the safety structure of their company and also help in achieving project completion goals within the time period and in less construction cost.

6.3.1 Guidelines

- Management should bring safety information to each employee at the construction site before starting work.
- Adequate training should be given to each employee to perform the job safely.
- Use of defective equipment should be prohibited at the construction site.
- Each employee should be educated so that he can recognize the hazardous situation.
- A safety supervisor should be placed at the site for solving safety problems.
- Safety site inspection should be done by higher safety authorities.
- Climate conditions of the area should be accepted for performing the job safely.
- Every task should be complete under safety guidelines.
- Each employee should know about safety measures.
- Under a risky environment, teamwork should be adopted.
- Employee’s feedback about safety at the construction site should be taken once a week so that safety performances can be improved.
- Management should organize campaigns to promote safe working practices.

6.4 Future Scope of Study

Similar Network can be develop for other projects because each project contain risk factors according to its nature of construction. Geographical location of projects can also be consider as a factor and it affect affects project depending upon the region. Education level can also be considered as a factor for performing unsafe practices at the site. Sometimes risk varies according to projects. Using these parameters and taking survey before starting work can reduce accidents.

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APPENDIX-A

QUESTIONNAIRE SURVEY REGARDING SAFETY AT CONSTRUCTION SITES

(Please tick the appropriate boxes where required)

Section I: Company / Department Profile

1.Company Name:	
2.Contact No (Optional):	
3.Nature of Company:	
Client	☐
Contractor	☐
Designer	☐
Consultant	☐
Other (Please Specify)	☐
4.Age of the Company:	
1-5 Years	☐
6-10 Years	☐
10-15 Years	☐
More Than 15 Years	☐

Section II: Respondent Profile

1.Name (Optional):	
2.Position in the Company:	
Site Supervisor	☐
Engineer	☐
Site Manager	☐
Any other (Please specify)	☐
3.Experience in the Construction Industry:	
1-2 Years	☐
3-4 Years	☐
5-6 Years	☐
7-10 Years	☐
10 Years and above	☐
4. Sex:	Male ☐ Female ☐

Section III:Likert Scale

Sr.no.	**Scale**	**Level of importance (Score)**
Level of Agreement		
1	Strongly Disagree	-1
2	Disagree	-0.5
3	Neither disagree nor agree	0
4	Agree	0.50
5	Strongly Agree	1

☐ All the information filled by me is best of my knowledge.

Question: Please, tick in the appropriate columns to indicate how much you agree that the following factors cause safety in construction projects.

S.No	Factors/Statement	SD	DA	NDA	AG	SA
F1	**Under Regulatory group**					
1.	Safety manager/supervisor implements safety rules and regulations.	1	2	3	4	5
2.	Management always appoint a safety representative on site.	1	2	3	4	5
3.	Safety manager/ supervisor generally engage in safety talks.	1	2	3	4	5
F2	**Under Work load group**					
4.	Management bear little unsafe behavior done by co-workers.	1	2	3	4	5
5.	Management make pressure to complete work on time.	1	2	3	4	5
6.	Working under rainy season is allowed sometimes.	1	2	3	4	5
F3	**Under Co Management group**					
7.	Everyone report accidents and hazardous situation on site.	1	2	3	4	5
8.	Everyone participate in safety planning.	1	2	3	4	5
9.	Each employees aim to achieve high level of safety.	1	2	3	4	5
F4	**Under Awareness group**					
10.	I know my duties toward safety.	1	2	3	4	5
11.	I know all the basic safety rules.	1	2	3	4	5
12.	Safety booklets issue to each employee	1	2	3	4	5

F5	**Under Encouraging group**					
13.	During work we remind each other how to work safely.	1	2	3	4	5
14.	We always offer help to group member to perform job safely.	1	2	3	4	5
15.	Under a risky environment, we do not support individuals to work by themselves.	1	2	3	4	5
F6	**Under safety Management group**					
16.	Management act soundly when safety matter is raised.	1	2	3	4	5
17.	Management always acts after an accident occurred.	1	2	3	4	5
18.	Management disciplines employees for working unsafely.	1	2	3	4	5
F7	**Under Equipment Group**					
19.	We use defective equipments.	1	2	3	4	5
20.	Management always use advance equipments.	1	2	3	4	5
21.	Management always hire experienced operator for heavy machinery.	1	2	3	4	5
F8	**Under Conveying group**					
22.	Management always acts to site employees' feedback.	1	2	3	4	5
23.	Management organize campaigns to promote safe working practices.	1	2	3	4	5
24.	Management always brings safety information to site employees.	1	2	3	4	5

F9	**Under Ability group**					
25.	I can identify harmful situations.	1	2	3	4	5
26.	I am fully trained to perform job safely.	1	2	3	4	5
27.	I always use protective equipments.	1	2	3	4	5
F10	**Under Protection group**					
28.	Management give safety training to each employee.	1	2	3	4	5
29.	Management provide safety equipment to all employees.	1	2	3	4	5
30.	Management involves in safety talks before start of any hazardous work.	1	2	3	4	5

Part- II

Please indicate yourself for safety practices on average 0-100%

1.	I follow all the safety rules during my job	

Thank you for contributing your valuable time, your honest information, and your thoughtful suggestions to complete this survey.

APPENDIX-B

निर्माण स्थल में सुरक्षा के संबंध में प्रश्नावली

(कृपया जहाँ आवश्यक हो, उपयुक्त बक्से पर टिक करें)

अनुभाग I: कंपनी / विभाग प्रोफाइल

1. **कंपनी का नाम**:	
2. **संपर्क नंबर (वैकल्पिक)**:	
3. **कंपनी की प्रकृति**:	
ग्राहक	☐
ठेकेदार	☐
डिजाइनर	☐
सलाहकार	☐
अन्य (कृपया निर्दिष्ट करें)	☐
4. कंपनी की आयु:	
1-5 साल	☐
6-10 साल	☐
10-15 साल	☐
15 साल से अधिक	☐

अनुभाग II: प्रतिसाद प्रोफ़ाइल

1. नाम (वैकल्पिक):	
2. कंपनी में पद:	
कार्यस्थल पर्यवेक्षक	☐
इंजीनियर	☐
साइट प्रबंधक	☐
अन्य (कृपया निर्दिष्ट करें)	☐

3. निर्माण उद्योग में अनुभव:	
1-2 साल	☐
3-4 साल	☐
5-6 साल	☐
7-10 साल	☐
10 साल और ऊपर	☐
4. लिंग:	पुरुष ☐ महिला ☐

अनुभाग III: महत्व स्कोर

अनु क्रमांक	स्तर	महत्व का स्तर (स्कोर)
समझौते का स्तर		
1	दृढ़तापूर्वक असहमत	-1
2	असहमत	-0.5
3	न असहमति और न ही सहमति	0
4	सहमत	0.50
5	दृढ़तापूर्वक सहमत	1

☐ मेरे द्वारा भरी गई सभी जानकारी मेरे ज्ञान से सर्वश्रेष्ठ है।

प्रश्न: कृपया, यह इंगित करने के लिए उपयुक्त कॉलम में टिक करें कि आप कितना सहमत हैं कि निम्नलिखित कारक निर्माण परियोजनाओं में सुरक्षा को प्रभावित करते हैं

अनु क्रमांक	कारक	SD	DA	NDA	AG	SA
	पर्यवेक्षण समूह के तहत					
1.	सुरक्षा प्रबंधक / पर्यवेक्षक हमेशा सुरक्षा नियमों और विनियमों को लागू करता है।	1	2	3	4	5

2.	सुरक्षा प्रबंधक / पर्यवेक्षक हमेशा सुरक्षा समस्याओं का समाधान करते हैं।	1	2	3	4	5
3.	सुरक्षा प्रबंधक / पर्यवेक्षक आम तौर पर सुरक्षा वार्ता में शामिल होते हैं।	1	2	3	4	5
	काम के दबाव समूह के तहत					
4.	मैं सहकर्मियों द्वारा किए गए थोड़े असुरक्षित व्यवहार को सहन करता हूं।	1	2	3	4	5
5.	प्रबंधन समय पर काम पूरा करने का दबाव बनाता है।	1	2	3	4	5
6.	बारिश के मौसम में काम करना कभी-कभी अनुमति देता है।	1	2	3	4	5
	कर्मचारी भागीदारी समूह के तहत					
7.	हर कोई साइट पर दुर्घटनाओं और खतरनाक स्थिति की रिपोर्ट करता है।	1	2	3	4	5
8.	हर कोई सुरक्षा योजना में भाग लेता है।	1	2	3	4	5
9.	प्रत्येक कर्मचारी का लक्ष्य उच्च स्तर की सुरक्षा प्राप्त करना है।	1	2	3	4	5
	प्रशंसा समूह के तहत					
10.	काम के दौरान मैं हमेशा सुरक्षा सुरक्षात्मक कपड़े पहनता हूं।	1	2	3	4	5
11.	मैं सभी बुनियादी सुरक्षा नियमों को जानता हूं।	1	2	3	4	5

12.	काम के दौरान मैं सुरक्षा के लिए अपनी जिम्मेदारियों को जानता हूं।	1	2	3	4	5
	सहायक पर्यावरण समूह के तहत					
13.	काम के दौरान हम एक दूसरे को याद दिलाते हैं कि कैसे सुरक्षित रूप से काम करना है।	1	2	3	4	5
14.	हम हमेशा सुरक्षित रूप से कार्य करने के लिए समूह के सदस्य को सहायता प्रदान करते हैं।	1	2	3	4	5
15.	एक जोखिम भरे माहौल में, हम व्यक्तियों को खुद से काम करने का समर्थन नहीं करते हैं।	1	2	3	4	5
	सुरक्षा प्रबंधन समूह के तहत					
16.	सुरक्षा मामला उठाए जाने पर प्रबंधन उचित तरीके से कार्य करता है।	1	2	3	4	5
17.	दुर्घटना होने के बाद प्रबंधन हमेशा कार्य करता है।	1	2	3	4	5
18.	प्रबंधन कर्मचारियों को बिना सोचे समझे काम करने के लिए अनुशासित करता है।	1	2	3	4	5
	उपकरण समूह के तहत					
19.	कुछ परिस्थितियों में खाराब उपकरण का उपयोग करने की अनुमति है।	1	2	3	4	5
20.	प्रबंधन हमेशा अग्रिम उपकरणों का उपयोग करता है।	1	2	3	4	5

21.	प्रबंधन हमेशा भारी मशीनरी के लिए अनुभवी ऑपरेटर को काम पर रखता है।	1	2	3	4	5
	संचार समूह के तहत					
22.	प्रबंधन हमेशा साइट कर्मचारियों की प्रतिक्रिया के लिए कार्य करता है।	1	2	3	4	5
23.	प्रबंधन सुरक्षित कार्य प्रथाओं को बढ़ावा देने के लिए अभियान आयोजित करता है।	1	2	3	4	5
24.	प्रबंधन हमेशा साइट कर्मचारियों के लिए सुरक्षा जानकारी लाता है।	1	2	3	4	5
	सक्षम समूह के तहत					
25.	मैं संभावित खतरनाक स्थितियों की पहचान करने में सक्षम हूं।	1	2	3	4	5
26.	मुझे सुरक्षित प्रदर्शन करने के लिए पूरी तरह से प्रशिक्षित किया गया है।	1	2	3	4	5
27.	मैं सुरक्षात्मक उपकरणों का उपयोग करने में कुशल हूं।	1	2	3	4	5
	सुरक्षा नियमों के तहत समूह					
28.	प्रबंधन प्रत्येक कर्मचारी को सुरक्षा प्रशिक्षण देता है।	1	2	3	4	5
29.	प्रबंधन सभी कर्मचारियों को सुरक्षा उपकरण प्रदान करता है।	1	2	3	4	5

30.	किसी भी खतरनाक काम की शुरुआत से पहले प्रबंधन सुरक्षा वार्ता में शामिल होता है।	1	2	3	4	5

कृपया 0-100% समय के औसत पैमाने पर इंगित करें

1.	मैं अपने काम के लिए सभी सुरक्षा नियमों का पालन करता हूं	

अपना बहुमूल्य समय, अपनी ईमानदार जानकारी और इस सर्वेक्षण को पूरा करने के लिए आपके विचारशील सुझावों में योगदान देने के लिए धन्यवाद।

APPENDIX-C

S.No.	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
1	0.833	-0.833	0.66	0.33	1	0.166	-0.33	0.833	1	-0.166
2	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
3	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
4	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
5	1	-0.833	0.66	0.33	0.83	0.166	-0.33	1	0.833	-0.166
6	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
7	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
8	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
9	1	-1	0.833	0.33	1	0.166	0.166	1	1	-0.166
10	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
11	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166
12	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
13	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
14	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
15	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
16	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33

17	0.833	-1	1	0.33	0.83	0.33	0.166	1	1	-0.33
18	1	-1	0.66	0.33	1	0.166	-0.33	0.833	1	-0.33
19	1	-0.833	1	0.33	0.83	1	0.166	1	0.833	-0.33
20	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
21	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33
22	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
23	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
24	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
25	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
26	1	-1	0.5	0.33	1	0.166	0.833	1	1	-0.33
27	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166
28	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
29	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
30	0.833	-0.833	0.66	0.33	1	0.166	-0.33	0.833	1	-0.166
31	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
32	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
33	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
34	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33

35	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
36	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33
37	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
38	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
39	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
40	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
41	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166
42	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
43	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
44	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
45	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
46	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
47	1	-1	0.5	0.33	1	0.166	0.833	1	1	-0.33
48	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33
49	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
50	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
51	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166
52	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166

53	0.833	-0.833	0.66	0.33	1	0.166	-0.33	0.833	1	-0.166
54	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
55	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
56	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
57	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
58	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
59	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
60	0.833	-0.833	0.66	0.33	1	0.166	-0.33	0.833	1	-0.166
61	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
62	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
63	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
64	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
65	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
66	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
67	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
68	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
69	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
70	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33

71	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166
72	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
73	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
74	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
75	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
76	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
77	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
78	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166
79	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
80	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
81	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166
82	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
83	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
84	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
85	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
86	1	-1	0.5	0.33	1	0.166	0.833	1	1	-0.33
87	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
88	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166

89	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
90	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
91	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
92	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
93	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
94	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
95	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
96	1	-1	0.66	0.33	1	0.166	-0.33	0.833	1	-0.33
97	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166
98	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
99	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
100	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
101	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
102	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
103	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
104	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
105	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
106	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33

107	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
108	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
109	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166
110	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
111	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33
112	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
113	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
114	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
115	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
116	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
117	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
118	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
119	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
120	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
121	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
122	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
123	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
124	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166

125	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
126	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
127	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
128	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
129	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
130	1	-1	0.833	0.33	1	0.166	0.166	1	1	-0.166
131	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
132	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
133	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
134	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
135	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
136	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
137	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
138	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
139	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
140	0.833	-0.833	0.66	0.33	1	0.166	-0.33	0.833	1	-0.166
141	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
142	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166

143	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
144	1	-1	0.833	0.33	1	0.166	0.166	1	1	-0.166
145	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
146	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33
147	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
148	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
149	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
150	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
151	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
152	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
153	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
154	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
155	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166
156	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
157	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
158	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
159	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
160	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166

161	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
162	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
163	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
164	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
165	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166
166	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
167	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
168	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33
169	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
170	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
171	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
172	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
173	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
174	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
175	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
176	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
177	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
178	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33

179	0.833	-0.833	0.66	0.33	1	0.166	-0.33	0.833	1	-0.166
180	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
181	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
182	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
183	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
184	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
185	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
186	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
187	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
188	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
189	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
190	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
191	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
192	1	-1	0.5	0.33	1	0.166	0.833	1	1	-0.33
193	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166
194	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
195	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
196	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33

197	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
198	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166
199	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
200	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
201	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
202	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
203	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
204	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
205	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
206	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
207	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
208	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
209	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
210	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
211	0.833	-0.833	0.66	0.33	1	0.166	-0.33	0.833	1	-0.166
212	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
213	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
214	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166

215	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33
216	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
217	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166
218	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
219	0.833	-0.833	0.5	0.33	1	1	-0.33	0	0.833	-0.33
220	1	-1	0.66	0.33	1	0.166	-0.33	0.833	1	-0.33
221	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
222	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
223	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
224	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
225	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
226	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
227	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
228	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
229	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
230	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
231	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
232	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166

233	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
234	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
235	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
236	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
237	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
238	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
239	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
240	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
241	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
242	1	-1	0.5	0.33	1	0.166	0.833	1	1	-0.33
243	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
244	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
245	0.833	-0.833	0.66	0.33	1	0.166	-0.33	0.833	1	-0.166
246	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
247	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
248	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
249	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
250	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166

251	1	-0.83	0.5	0.33	0.83	0.33	-0.33	0.833	1	-0.33
252	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
253	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
254	1	-1	1	0.33	0.166	0.33	-0.33	0.833	1	-0.33
255	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
256	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33
257	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
258	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
259	1	-0.33	0.66	0.33	0.83	1	-0.33	1	1	-0.166
260	1	-1	1	0.33	1	0.33	0.166	1	0.833	-0.33
261	0.833	-1	0.66	0.5	1	1	0.166	1	0.833	-0.166
262	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
263	1	-0.33	1	0.33	0.83	1	-0.33	0.833	1	-0.166
264	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
265	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
266	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166
267	1	-0.833	1	0.33	0.83	1	0.166	0.833	0.833	-0.33
268	1	-1	0.5	0.33	1	1	-0.33	0.833	1	-0.33

269	0.833	-0.833	1	0.33	1	0.166	-0.33	0.833	1	-0.33
270	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
271	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
272	1	-1	0.833	0.33	1	0.166	0.166	1	1	-0.166
273	0.833	-0.33	0.5	0.33	1	0.33	0.166	0.833	1	-0.166
274	1	-0.833	1	0.33	1	0.166	0.166	1	0.83	-0.166
275	0.833	0.66	0.5	0.33	1	0.33	0.166	0.833	1	0.166
276	1	0.66	1	0.33	0.166	0.166	0.166	0.833	1	-0.33
277	1	-0.833	0.66	0.33	0.83	0.166	-0.33	1	0.833	-0.166
278	1	0.66	1	0.33	1	0.166	0.166	0.833	1	-0.33
279	0.833	0.66	0.5	0.5	1	0.33	-0.33	0.833	1	-0.33
280	1	-1	0.833	0.33	1	0.166	0.166	1	1	-0.166
281	0.833	0.66	1	0.3	1	0.166	0.166	0.833	1	-0.33
282	1	-1	0.66	0.33	1	0.166	-0.33	1	0.833	-0.166

APPENDIX-D

Factor analysis of 10 safety groups

Table 1. KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.759
Bartlett's Test of Sphericity	Approx. Chi-Square	1148.25
	df	527
	Sig.	.000

Table 2. Value of variance explained

Total Variance Explained						
Component	Initial Eigen values			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.366	23.656	23.656	2.366	23.656	23.656
2	2.233	22.329	45.986	2.233	22.329	45.986
3	1.478	14.785	60.771	1.478	14.785	60.771
4	1.014	10.137	70.908	1.014	10.137	70.908
5	.886	8.860	79.768			
6	.705	7.050	86.817			
7	.525	5.254	92.071			
8	.444	4.439	96.510			
9	.253	2.525	99.035			
10	.096	.965	100.000			
Extraction Method: Principal Component Analysis.						

Table 3. Random Eigen value from Monte Carlo PCA parallel analysis

Component	Random Eigen Value	Standard Deviation
1	1.3254	0.0473
2	1.2138	0.0297
3	1.1326	0.0233
4	1.0698	0.0263
5	1.0045	0.0187
6	0.9591	0.0233
7	0.9070	0.0225
8	0.8601	0.0229
9	0.7982	0.0239
10	0.7295	0.0362

Table 4 Comparison of initial eigen value and random eigen value from parallel analysis

Initial Eigen values				Parallel Analysis		Comment
Component	Total	% of Variance	Cumulative %	Component	Random Eigen Value	
1	2.366	23.656	23.656	1	1.3254	Retained
2	2.233	22.329	45.986	2	1.2138	Retained
3	1.478	14.785	60.771	3	1.1326	Retained
4	1.014	10.137	70.908	4	1.0698	Not Retained

Table 5 Communalities values for 10 groups

Communalities		
	Initial	Extraction
1	1.000	.750
2	1.000	.845
3	1.000	.737
4	1.000	.804
5	1.000	.827
6	1.000	.726
7	1.000	.785
8	1.000	.968
9	1.000	.831
10	1.000	.704
Extraction Method: Principal Component Analysis.		

Table 6 Component Correlation Matrix

Component Correlation Matrix			
Component	1	2	3
1	1.00	0.561	0.617
2	0.561	1	0.59
3	0.617	0.59	1
Extraction Method: Principal Component Analysis. Rotation Method: Oblimin with Kaiser Normalization.			

Components are correlated because values are greater than 0.5.

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