What Makes a Project Safe?
Identifying the Impacts Factors Have on the Safety Performance of a Construction Site through Use of Artificial Neural Networks

by

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Abstract

What makes a construction project safe? This question prompted this research project. The goal was to identify factors and quantify their impact on the safety performance of construction projects. The first step in achieving this goal was to research key performance indicators in the area of safety and to identify common factors associated with safety in construction. A list of factors was created and presented to building construction industry members to establish causation for the factors and to eliminate any factors that did not have available data. The set of revised factors was not adequate to represent a construction project and did not fully capture the nature of their safety aspects. Safety professionals were interviewed to determine additional factors that were associated with the behavior of personnel on building sector construction sites. Historical data was collected from projects completed by a construction contractor, and this data was used to represent the revised list of factors that had been established with input from industry members. The project managers from the projects were surveyed to obtain data for the other factors identified through the interviews conducted with safety professionals. Using the historical data and information collected from surveys, a feed forward-backward artificial neural network was developed to analyze data and identify the impact that each of the factors had on safety performance. The neural network used a sigmoid transfer function with a single hidden layer. Three unique configurations of models were experimented with. Each configuration used the same data that was collected from historical project information and the surveys of project managers, as well as the same network topography; however, how the data was organized changed with each configuration. The results from each configuration had some variation but showed similar findings. The factors with the highest importance amongst all three configurations were factors that related to safety inspections and project manager mentoring.

Preface

This thesis is an original work by Lance Cooper. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name “An Investigation into Factors That Make Projects Safe,” No. 0034261, 7/26/2013.

Acknowledgement

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Table of Contents

List of Tables

List of Figures

2. Introduction

Overview

What makes a construction project safe? This was the question that was asked at the being of this project. Construction projects are very complex in nature, they consist of a large number of individuals coming together to complete multiple tasks, in a particular order, within a specific amount of time, meeting an acceptable level of quality, without incurring injuries, and in the end producing a product (such as a road, bridge, structure, pipeline) that meets the original plan of the project.

The safety aspect of a construction project has become a big concern because worker injuries cause tremendous losses (Fang, Huang and Hinze, 2004). Safety in construction is very complex because it is not only affected by the physical aspects of the project, but is also largely impacted by the personnel on the project. After speaking with multiple project managers and safety professionals, a common theme surfaced that having a “good” safety culture on the project is crucial to having a safe project. They described safety culture as the attitude towards safety that is passed from the top down through the line of command eventually reaching the front line workers. If management sets a positive attitude towards safety and places a high value on making sure things are done in a safe manner, then this attitude will be reflected in the attitude of the workers. If the attitude from management towards safety is negative and poor safety behaviors are not corrected and properly coached, a negative safety culture will develop. Workers will not feel pressured to wear the required personal protective equipment (PPE) or will “cut corners” when completing tasks. It was for this reason that personal behaviors of project management personnel was included as part of this study.

To answer the question of what makes a project safe, a goal was created to identify a list of factors and quantify their impact on the safety performance of a construction project. A review of literature was conducted on studies that focused on safety in construction. There has been substantial research conducted on benchmarking in construction, with many of those studies focusing on the area of safety. This was the starting point for identifying a list of factors. The factors in this list all pertained to historical information collected on a project site. Interviews were conducted with industry members from the building construction sector to obtain their perspective on this list. They identified factors from their experience they felt needed to be included in this study and eliminated factors they knew could not be collected due to insufficient data. It was through these interviews that the topic of safety culture was first introduced and where the need to include project management personnel behaviors as part of this study arose. With input from the industry members, a list of behavioral based factors in regards to project management was drafted. This list was then brought forward to project site safety professionals, in the form of a second set of interviews, to gain their perspectives. They provided guidance on what factors were important, what factors were missing, and how to measure them. Using this updated list and the advice on how to measure the factors, a survey was created. This survey would be administered in person to the project managers and the information collected would be cleaned and organized into the behavioral based factors.

In order to analyze the collected data for these factors a model that can incorporate all the factors was developed. An artificial neural network model was chosen because these types of analytical models are capable of sorting out hidden patterns and extracting predictive information from complex data sets, and have been proven to be effective in both uncertainty analysis and sensitivity analysis of construction related topics (Lu, 2000). A feed-forward backward propagating neural network was developed, using a sigmoid transfer function and a single hidden layer. Using this neural network, the goal of the study to identify factors that affect safety and determine their impact on the safety performance of a project could be achieved.

Objectives

The objective of the project was to establish a set of factors, measure their impact on the safety performance of a project, and develop a neural network model to analyze this set of factors. In order to achieve these objectives, the following goals needed to be met:

- Identify factors that affect the safety performance of a construction site.
- Collect historical data and administer surveys to collect data for behavioral based factors.
- Organize and clean data in their respective factors.
- Develop artificial neural network for analysis of factors.
- Quantify impact of identified factors on the safety performance of a construction site.

Scope of Research

The research done in this study was conducted with a single construction contractor operating within the building sector. Information gathered and used within this study was from projects completed between 2005 and 2012, all located in Alberta.

Expected Contributions

The expected contributions of this study were:

- Gathering of information from experts and combining with hard data for analysis.
- Identifying project management behaviors that have an impact on safety performance.

- Identifying data that should be collected in the future to achieve a better measure of safety performance.
- Quantifying the impact of factors on the safety performances of construction projects.

Thesis Organization

Chapter 2 is a review of the literature, and discusses the state of the art. Factors affecting safety and neural network applications in construction were also discussed. Chapter 3 discussed both the historical data and behavioral based factors affecting safety and how the data was collected to obtain the factors. Chapter 4 summarizes artificial neural networks, the implementation of the model, and provides conclusions of the study. Chapter 5 suggests potential future research and provides concluding remarks.

3. Literature Review

Introduction

The literature review has two main focuses: investigating and gathering information on factors that affect the overall safety performance of a construction project, and investigating the use of artificial neural networks as a tool to estimate the impact that each of the factors have on the safety performance.

Factors that Affect Safety Performance

Fang, Huang, and Hinze (2004) collected data to establish a safety benchmark. Their study used a combination of project safety assessment tool sheets and a series of questionnaires of key personal (project managers, safety supervisors, foremen, and workers). Factors focused on included:

1. Project nature:
    a. Size of the project: The height of the work, the total area, total projected cost of the project
    b. Complexity of project construction: Ratio of site area to building area, application of new technology, complexity of the design
    c. Complexity of project management: Quantity of workers on site, number of layers of management, number of subcontractors
2. Historic factors:
    a. Age and experience: Age, education years, years working in construction industry, years working on the project, safety training received, marital status

   b. Percentage of new workers on site: Percentage of workers that have been working in construction for less than 1 year, percentage of workers that are new to the project
   c. Accident experience: Whether any accidents have happened in the past 3 months, whether the worker has been injured in an accident, whether the worker has witnessed any accidents
   d. Experience of safety punishment and rewarding: Whether the worker has been punished because of unsafe performance, whether the worker has been punished for unsafe actions
3. Organizational structure:
   a. Quantity of safety supervisors: The ratio of the number of workers to safety supervisors, the ratio of the building area to safety supervisors
   b. Involvement of contractor top management: Whether top management inspects site safety regularly, whether top management checks safety records of the project, the most important contractor concerns
   c. Authority of safety supervisors: Whether the safety supervisor has authority to stop site work for identified hazards
   d. Authority of foreman: Whether the foreman has extensive authority of the crew
   e. Size of the crew: number of workers in the crew
4. Management measures:
   a. Safety inspection: Frequency of safety inspections conducted by the safety supervisor, by the project manager, by the contractor, by the owner (representative), by the local authority

b. Safety meetings: Frequency of safety meetings convened by the safety supervisor, attendance of project manager at the safety meetings, whether any safety meetings are attended by workers before each activity beings
c. Safety plan and record: Whether there is a detailed safety plan before each activity begins, whether daily safety records are kept
d. Safety rewards: Whether there is any reward for safe workers, whether there is any reward to workers with high productivity, the maximum fine to workers without hard hats
e. Safety training: Whether there is any safety training of new workers, the effect of the safety training
f. Other safety measures: Whether workers are encouraged to work with their friends, whether the schedule pressures are passed on to the workers, whether workers with obvious mental distractions are required to stop work

5. Individual involvement:
    a. Safety knowledge: Safety quiz results
    b. Safety awareness: Safety awareness results
    c. Safety involvement: Worker involvement in safety activities and compliance with safety requirements
6. Economic investment:
    a. Safety investment: Ratio of safety investment to total project volume
    b. Workers' compensation insurance: Whether the contractor buys workers' compensation insurance for workers

    c. Safety investment on PPE: Average investment on worker's PPE on the project, whether the project provides adequate PPE to each worker, whether the contractor pays for the medical expenses of injured workers

7. Management-labor relations:
    a. Relations between management and labor on site: Duration that the contractor has cooperated with the labor subcontractor, percentage of the workers on site that are familiar to the project management staff

de la Garza, Hancher, and Decker (1998) issued questionnaires to contractors broken down into two sizes, large (received contracts worth a total sum of >$100,000,000) and small (sum of contracts received <$100,000,000). They also looked at whether or not their work was primarily (>75%) open shop or union based. They focused on rates rather than factors; the rates they looked at were:

1. Experience Modification Rate (EMR)
2. OSHA Recordable Incident Rate (RIR)
3. OSHA Lost Time Incident Rate (LTIR)
4. Workers' Compensation Claim Frequency Indicator (WCCFI); represents the number of workers' compensations claims filed for a given company in a single year per 200,000 hours

They found the EMR and RIR to be too sensitive to company size and not good indicators when used individually. The WCCFI was sensitive to the difference between union based and open shop contractors. Their recommendations from the study were:

1. Avoid using a single indicator as a measure of contractor's safety performance. Instead, use the collective criteria formed by the contractor's EMR, RIR, LTIR, WCCFI, and its explicit commitment to zero-injuries.
2. Educate employees, employers, and employee representatives about workers' compensation and its impact on business.
3. Participate in the selection of medical providers, focusing on those who believe in getting the injured worker back to work as soon as is medically practical.
4. Utilize modified work programs for injured employees where they can perform productive duties without exposing themselves or their coworkers to further injury.
5. Take an active role in interfacing with the insurance carrier or provider.
6. Participate in validating, approving, or denying employees' workers' compensation claims, including vigorous opposition and investigating fraud.
7. Maintain frequent contact with injured employees. Make sure their needs and expectations are being met and keep them abreast of jobsite activities.
8. Establish accountability for workers' compensation costs with projects and supervisors.
9. Provide on-site first aid treatment appropriate to the size of the project.

Priyadarshani, Karunasena, and Jayasuriya (2013) looked at benchmarking safety performance in developing countries through a mean score method. They then used that mean score to calculate a relative importance of each factor and come up with a total score for all the factors and categorize the overall performance into three categories based on total score: poor, satisfactory, and good. The factors they looked at were:

1. Management Commitment
    a. Developing safety policies

    b. Assigning safety responsibilities to site personnel
    c. Developing in-house safety rules
    d. Establishing safety management system with adherence to legislation codes and standards
    e. Communication between management and workers at the site
2. Implementation
    a. Provision of plant and equipment maintenance
    b. Conducting site safety inspections and supervision
    c. Employment of safety officer and safety supervisor
    d. Provision of safe working environment
3. Management Measures
    a. Safety meetings
    b. Safety plans and records
    c. Safety rewards/incentives
    d. Safety training
4. Project Nature
    a. Size of project
    b. Complexity of project
    c. Number of subcontractors
5. Individual Involvement
    a. Safety knowledge
    b. Safety attitude
6. Economic Investment

   a. Safety investment
   b. Workers compensation insurance

They found in their research that all the factors used are important and none were rejected. The factors under management commitment section were the most important in the case of more complex projects.

Farooqui, Arif, and Rafeeqi (2008) looked at the safety performance of construction companies in Pakistan. They used two indexes based on identified factors, the first being the safety non-performance index and the second being the safety performance index. The factors are related by the equation safety performance index = 1 – safety non-performance index. They scored the sites into five categories based on the safety performance index: extremely unsafe, unsafe, moderately unsafe, safe, and extremely safe. The factors used to create both indexes are as follows:

1. Self-Protection Category
   a. Safety helmets not worn
   b. Protective footwear not worn
   c. Gloves not worn
   d. Ear defenders not worn
   e. Goggles or other items of eye protectors not worn
   f. Face masks not worn
2. House Keeping Category
   a. Timbers left lying around, have nails left in
   b. Openings left uncovered or unguarded
   c. Stored materials are stacked/ stored unsafely

d. Walkways, access routes and staircases are littered with rubbish/debris

e. Proportions of operatives, who are working at heights, seen throwing down objects

f. Tools or small machinery not placed or stored properly

g. Excavations not provided with safety mesh erected all around

3. Scaffolding Category

a. Working scaffold platforms missing boards

b. Scaffold boards placed incorrectly, causing a 'trap'

c. Toe-boards missing on working scaffold platforms

d. Guardrails are missing on working scaffold platforms

e. Scaffolds/formwork missing base-plates under the standards

f. Site personnel, who are working at heights, are climbing up or down the outside of scaffolds

4. Access to Heights Category

a. Ladders too short for the jobs

b. Ladders used without being tied or secured

c. Ladders used unsafely

d. Ladders placed with broken or defective rungs

e. Mobile tower scaffolds used unsafely

f. Mobile Work Platforms (MWP) being used unsafely

Their findings showed that the top three safety non-performance practices for building construction work were: ear defenders not worn, protective footwear not worn, and face masks not worn.

Duff, Robertson, Phillips and Cooper (1994) studied the improvement of safety by modifiying behaviors of construction projects in northwest England. They looked at four categories to measure:

1. Access to heights
2. Site housekeeping
3. Scaffolding
4. Use of personal protective equipment (PPE)

They used three intervention procedures to modify behaviors in construction:

1. Goal-setting
2. Feedback charts
3. Training

Their results showed that behaviors did have an impact on safety performances, and that goal-setting and feedback used together had the strongest influence, combining all three had a slightly weaker influence, and using both training and feedback only had the weakest influence. Although they did not attempt to evaluate the effect of management commitment, they found that it had a significant impact on their results. They were able to correlate that the companies that had highest performance were the companies whose management had the most engagement in safety.

Ikma, Nahmens, & James (2011) looked at the impact that productivity and safety had on each other by applying a lean approach (productivity) and job safety analysis (safety). They found that by increasing productivity through use of the lean approach, the number of safety incidents were also reduced.

Goggin, Willis, & Rankin (2010) focused on studying the realitionship between the maturity of a companies safety management practices and their safety preformance. They found that they required input from experts to have meaningful results.

Lingard, Cooke, & Blismas (2012) investigated the factors that described the safety climate or culture of the construction site and related it to the injury rate of the focused projects. They found that first-level supervisor played a pivitoal role in communicating the companies safety priorities to the work force and therefore played a key role in the safety performance of that company.

Leung, Chan, & Ka-Wing (2010) researched the impact that job stress and emotional stress of construction workers had on the number of injury incidents occuring on the project. They found that emotional stress had an impact on the number of injuries whereas job stress did not.

Hinze, Hallowel, & Baud (2013) performed a study to identify the impact that various construction-safety strategies had on projects recordable incident rate. They found of the 104 strategies studies, 14 strategies impacted safety performance.

Hinze, Devenport, & Giang (2006) studied the types of injuries that did not result in lost time. The goal was to see if there were factors that could be identified which caused the occurance of these injuries. They found the the majority of the incidents involved lacerations, and should be a major focus to reduce the number of injurys on a construction project.

Hinze & Gambatese (2003) looked into factors that impact the safety performance of specialty contractors. They focused on speciality contractors because they perform the majority of the contruction work in the building sector. They found that minimizing worker turnover, drug testing, and training improved performance; whereas incentive programs did not necessarily.

Hinze, Pederson, & Fredley (1998) attempted to identify factors that cause construction injuries.They found the collected information at the time was not adequate and instead came up with some recommendations on how to make OSHA reports more meaningful by grouping injuries into 20 unique group types rather than the 5 they were using.

Hinze & Wiegand (1992) analyzed the role of designers on the safety of construction workers. They found that only a third of the designers surveyed considered safety in their designs. They suggeted a paper be developed looking at the impact the design of the project has on the safety performance of the project.

Hinze (1987) looked at what factors make a safe superintendent. He found that superintendents with good management skills that did not fall behind schedule had better safety performance on their projects.

Hinzie & Rabound (1988) created a study to assess the degree that company policies and practices had on the safety performance of a project. They found that having a full-time safety officer, holding safety meetings with supervisors, and those that monitored safety performance had safer projects.

Hinze (2005) researched the pratices that influence safety performance on power plant outages. One of his findings was shutdown projects that used a cost plus contract type had safer performance.

Chen, Jin, & Soboyejo (2013) aimed to understand the variation between a contractor's regional office in terms of safety performance. They found that region played a key role in the safety performance. Their study showed that despite having the same safety programs in place, each region had different injury rates.

McCabe, Karahalios, & Loughlin (2005) looked at different aspects of workers on construction projects to see the impact of safety culture and performance. They found that experience and age of the worker contributed to having a postive attitude, but they could not correlate that information to mean a safer worker.

Artificial Neural Networks

A neural network is an information processing tool which was modeled after the human brain. A neural network is a set of mathematical models that are designed to function in a similar manner to that of the human nervous systems and mimic its adaptive biological learning. Neural networks are a strong tool to be used when there is a complex relationship between variables. A neural network is a set of trained data consisting of known inputs and outputs. The network develops weights that each of the input factors has on the output factors based on the training data. The weights are determined by using the input data to compute an output. The network then checks against the output from the training data and the error between is checked. If it's acceptable, the neural networks weights are determined, if the error is not acceptable the weights are adjusted and the process is repeated until the error is acceptable. Neural network will be discussed in greater detail in chapter 4.

Artificial Neural Networks in Construction

Artificial Neural networks have been used in construction with some success. Goh and Chua (2013) used a neural network to do an analysis of construction safety management systems in Singapore. They used 13 elements of an occupational safety and health management system

(OSHMS) as the inputs and a three level accident severity classification as the output for the network. The 13 input elements were:

1. Safety policy
2. Safe work practices
3. Safety training
4. Group meetings
5. Incident investigation and analysis
6. In-house safety rules and regulations
7. Safety promotion
8. Evaluation, selection and control of subcontractors
9. Safety inspections
10. Maintenance regime for all machinery and equipment
11. Hazard analysis
12. The control of movement and use of hazardous substances and chemicals
13. Emergency and preparedness
14. Occupational health and programme

The three level accident severity classification used for the network outputs was:

1. An A case involves a temporary disablement injury with more than three days' medical leave or more than 24 hours of hospitalization
2. A B case involves a permanent disablement injury where the injured is unable to undertake any type of work or it results in a reduction of earning capacity
3. A C case involves at least one fatality

They found the prediction performance of their network to be reasonably accurate. They determined that improvement in incident investigation and analysis, emergency preparedness and group meetings would have the biggest positive impact on accident occurrence and severity. They also found that improvement of safety promotion, safety training, safety inspections, and safety rules and regulations had a negative impact on network output. Their research supports the idea that artificial neural networks are a suitable tool for problems that are non-linear in nature.

Palaneeswaran, Love, Kumaraswamy and Ng (2008) used a series of artificial neural networks to do analysis on the causes and effects of rework. They used ANN (artificial neural networks) to model six project performance parameters: cost, time, contractual claims, client dissatisfaction, and design team dissatisfaction. Each of their ANNs were run using both 15 inputs to a single output and 28 inputs to a single output. For all three ANNs they used both a back propagation neural network (BPNN) and a general regression neural network (GRNN). They found that the GRNN produced better results than those from the BPNN for use in determining the causes and effects of rework.

Portas (1996) experimented with feed-forward artificial neural networks to estimate concrete formwork productivity. He tested the predictability and error differences of using both a sigmoid transfer function and hyperbolic tangent function within his neural network. He found using the hyperbolic transfer function would produce erratic results during training. He found the sigmoid transfer function was best used with his data collected from various construction projects.

Lu (2000) used artificial neural networks to analyze the variability of actual labor production ratios of pipe spool fabrication and identify sensitivity of identified influencing factors. He found that back propagating artificial neural networks (BPNN) were an effective tool at reducing the required amount of data when compared to linear regressions analysis. He also found that BPNN were an effective tool for input-output mapping for multiple outputs whereas linear regression analysis was limited to a single output.

Muqeen, Idrus, Khamidi, Ahmad and Zakaria (2011) utilized artificial neural networks to predict the productivity of formwork of beams used in high-rise concrete building construction. They used surveys to identify and eliminate factors that would then be recorded and collected from construction projects. In their neural network they used 5 input nodes and a single output node. The hyperbolic tangent function was selected as their transfer function and found the model predicted the productivity of beam formwork within an acceptable range of error.

State of the Art

The area of safety is very complex and has been the focus of study for many years. Many studies have looked at what factors should be used in safety. Other studies have looked at measuring safety performances by creating a key performance indicator or benchmark and comparing projects scores based on that value. There have been studies that have investigated behaviors of personnel and their impact on safety. There have been no studies that have looked at combining safety performance information and the behaviors of management from construction projects and identifying the specific impact of each factor on safety performances of construction projects.

Artificial neural networks have been used in the construction industry for many purposes, usually relating to productivities of various constructions tasks. They have not been used to measure the impacts that factors, particularly in the area of behaviors of personnel, have on the safety performance of construction projects.

4. Data Collection

Introduction

The data collection process for determining which factors affect the safety performance of a construction site in the building sector consisted of identifying what data to collect and how to collect it. Figure 3.1 illustrates the collection of data completed in this study.

The concept of representing a building sector project through a set of data was used to identify the information that would need to be collected. A construction project was looked at from three different perspectives: the first was to have a set of factors that would describe the size, scale and complexity of a construction project, the second perspective was to look at what has been done to mitigate any potential safety incidents, and the third perspective was to look at a construction project's safety performance.

While keeping these perspectives in mind, a review of literature was completed to create a list of desired data to be collected. The intent of this list was to create a set of factors that could be used to analyze the safety performance of a construction project. This list was presented and discussed with project management staff, resulting in two revised lists of factors that could be feasibly collected from historical project data. A third set of factors was also created through these discussions; these factors could not be collected from historical project data. This set was based more on the people and their behaviors on the construction site, rather than the site itself.

Safety professionals were interviewed for their perspective on how to collect these behavioral/non-historic factors. They were also questioned on which factors they thought may have an impact on the safety performance of a construction project. The interviews with safety professionals helped provide direction as to which factors to focus on and to establishing causation to the lists of factors already created. Six ideas or themes were consistently mentioned by all safety professionals interviewed. The identified themes were then used to create a list of factors that would need to be collected by interviewing project management staff. Discussions with industry members were held on the topic of the best way to get project managers to participate. It was determined that a survey administered in person or via phone message would yield the highest participation rate. Contact was made to the project managers through a message sent from the regional manager of the company, which also helped with participation.

Based on the information gathered through the interviews of safety professionals, a survey consisting of 20 questions was created. The questions were designed to have an answer that was either an absolute number or a percentage. The purpose behind this was to be able to turn that number or percentage answer into a data point that would represent one of the factors identified through discussions with the safety professionals. 19 factors were created from the data collected through the administered surveys.

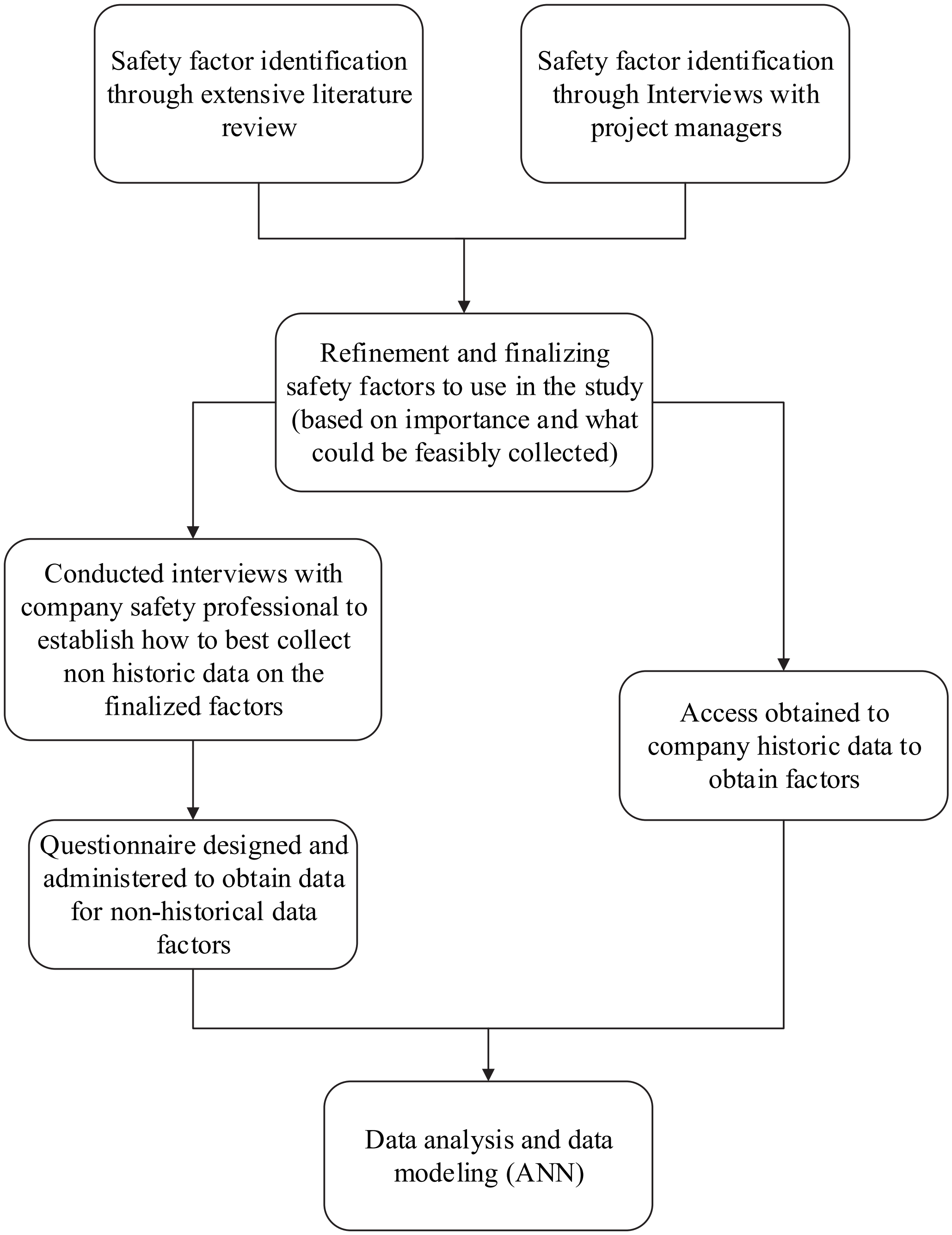


Figure 4.1

Prior to administering the surveys, ethics approval was obtained; the application and approval can be found in Appendix A. Once the data was collected it was cleaned and organized into two categories that would be used by an artificial neural network to analyze the impact that each of the factors had on the safety performance of a construction project. The two categories were labeled as inputs, independent factors and outputs or dependant factors. The input category consisted of both the historical data collected from the project information as well as the results compiled from the surveys. The output data was the information related to the safety performance of the construction sites. This set of inputs and outputs became the basis for the artificial neural network (ANN) model.

Types of Data Collected

The data collected can be categorized into two major groups: historical data and non-historical or behavioral-based data.

Historical Data

The historical data was the information taken from databases that stored the information collected as part of the project. This information was entirely numeric. It was the starting point for developing a profile that would be used to represent a construction project as a set of factors. The historical data was used for a portion of the inputs and made up the entire outputs used in the ANN. The historical data collected was easily accessible because the contracting company had created databases to store this data for use within the company. It was simply a matter of gaining access to the database and pulling the information that was required. This data also required less cleaning for use in the ANN when compared to the non-historical or behavioral based data as it was already in a numerical form that could be used as data points within the model without any additional work required.

Behavioral-Based Data

It is widely argued that safety has strong ties (Duff, Robertson, Phillips, & Cooper, 1994) to the behavior of the personnel on the construction project. Utilizing this knowledge, data was collected that describes the behaviors of personnel on site. A review of historical data showed that this aspect had not been represented and would also need to be collected. The behavior-based data collected consisted of both qualitative and quantitative data. This data was considerably more challenging to collect when compared to the historical data. This can be attributed to the fact that the data was not in a concrete obtainable form and was very subjective in nature. It existed only in the form of thoughts and perspectives of the project management team that worked on the projects that had the historical data collected. Interviews were conducted with both safety professionals and management staff in order to determine what could be collected from the personnel on site and how to collect it. The knowledge gained from these interviews was used to create a survey that would be used to turn thoughts and preservatives of project management personnel into concrete data.

List of Factors Collected

An initial list of historical factors was created by reviewing literature. This list consisted of factors that would later become inputs and outputs for use in the ANN model. The list was created and split into three groups: safety performance measures, safety due diligence measures, and project profile data. The first set of factors would be the outputs of the ANN model and used to measure the safety performance of a construction site. The second set of factors were used as inputs to the ANN model and represented the company's due diligence towards safety. The third set is list of historical data factors that could be used to create a profile representing the size, scale, and complexity of the project. These project profile factors will be used as inputs for the ANN model.

The set of safety performance measures consisted of the following factors:

- Lost Time Incidents (LTI): An incident that occurred which resulted in productive time being lost
- Days Lost (DL): The number of days that were lost from a LTI
- Medical Aids (MA): The number of incidents that required a physician's assistance
- First Aid (FA): The number of incidents that occurred that required medical attention but not from a physician
- Modified Work (MW): The number of incidents that occurred that resulted in the worker involved in the incident requiring their work to be modified after the incident
- Modified Work Days (MWD): The number of days of work that were required to be modified for a worker after a MW incident occurred
- Site Specific Hazard Assessment (SSHA) completed: The number of SSHA that were completed by workers
- SSHA audits: The number of SSHA that were audited by site management staff ensuring that the SSHA were being properly completed
- Inspections completed: The number of safety inspections completed by project management and safety staff

For definitions of hazards, see Figure 3.2 referenced below (taken from the contracting company's Health and Safety manual).

Risk Category		Definition
"A"	High (8-16)	Situation must be corrected immediately. Approval to continue at current level of risk by District Manager, Senior Construction Manager and District HSE Manager.
"B"	Medium (4-6)	Approval to continue at current level of risk by 2 senior supervisory project team members.
"C"	Low (1-3)	Managed appropriately at field level.

Frequency of Task		
Category	**Term**	**Definition**
4	**Very Frequent**	Possibility of repeated activities (many times in the course of a task)
3	**Frequent**	Possibility of isolated activities (several times in the course of a task)
2	**Occasional**	Likelihood of activity occurring sometime (likely in overall task and/or project)
1	**Infrequent**	Possible it will occur but not likely to

Severity – Consequences					
Consequence Category		**People**	**Property**	**Environment**	**Public Image, Reputation & Disruption**
4	**Major**	Fatality	Impact >$100,000	Reportable Occurrence	Government intervention
3	**Critical**	Permanent, long-term injury or illness	Impact < $100,000 but > $50,000	Client Standards Not Met	Owner Intervention
2	**Serious**	Recordable Injury	Impact < $50,000 but > $ 10,000	Site Conditions Unacceptable	Community Attention
1	**Minor**	On-site/ No Treatment	Impact < $10,000	No Impact	Individual or none

		Frequency of Task			
		4	**3**	**2**	**1**
Severity	**4**	16	12	8	4
	3	12	9	6	3
	2	8	6	4	2
	1	4	3	2	1

Figure 4.2

The set of safety due diligence measures were the following factors:

- Site Specific Hazard Assessment (SSHA) completed
- SSHA audited
- Inspections completed

The initial set of factors to create the project profile consisted of the following:

- Total manhours worked on the project
- Total overtime (OT) hours worked on the project
- Percentage of hours worked by each trade on the project with respect to the total manhours worked on the project
- Percentage of OT hours worked by each trade on the project with respect to the total OT hours worked on the project
- Type of workers used on site (union/non-union)
- Number of subcontractors used on site
- Average experience level of workers on site
- Average age of workers on site
- Average crew size on site
- Average weather conditions during project duration
- Value of the project
- Complexity of the project
- Number of requests for information (RFI) submitted by the contractor
- Quality of Engineering
- Pre-planning of work

- Number of change orders submitted
- Percentage of project budget allocated for safety expenses
- Quality of project safety plan
- Number of safety meetings
- Frequency of safety meetings
- Amount of training safety for workers

These initial lists were brought forward to a contracting company that had agreed to give feedback and access to their project databases. Discussions on the proposed factors were conducted with project managers and the district safety manager of the company. These discussions had the goal of determining causation between the safety due diligence factors, the project profile factors, and the safety performance measures. The discussions brought up the need to collect data from enough projects so that any analysis would have statistical relevance. It was for this reason that many of the factors had to be eliminated from the list. In order to have enough projects to collect data from, the time frame of projects increased. Many of the factors on the list the company had started to collect as part of their project data, but they did not have enough projects in their database that had started collecting the information required for that factor. It was for this same reason that any information related to the details of the individual workers had to be removed from the list. Information from timecards was available so information related to the trade of the work could be obtained. As part of the information collected on the timecards, the company tracked the level classification of some trades. For example, a craftsman would be recorded as craftsman I, craftsman II, craftsman III, and craftsman IV based on the years of work and training of the worker. This was used to represent the experience of the workers, but had to be eliminated because of the inconsistency of classifications between trades (a craftsman II wouldn't have the same experience and training compared to a supervisor II).

After revising the lists of factors, they consisted of the following:

Safety performance measures:

- Lost Time Incidents (LTI)
- Days Lost (DL)
- Medical Aids (MA)
- First Aid (FA)
- Modified Work (MW)
- Modified Work Days (MWD)
- Number of Level A Hazards Identified
- Number of Level B Hazards Identified
- Number of Level C Hazards Identified

Safety due diligence measures:

- Site Specific Hazard Assessment (SSHA) completed
- SSHA audited
- Inspections completed

Project profile factors:

- Total manhours worked on the project
- Total overtime (OT) hours worked on the project

- Percentage of hours worked by each trade on the project with respect to the total manhours worked on the project
- Percentage of OT hours worked by each trade on the project with respect to the total OT hours worked on the project
- Value of the project
- Duration of project
- Project contract type

Everyone involved with the study agreed the project profile would need additional factors to get a more in-depth description of the projects they were representing. Part of the information kept by the construction company was the identity of the project manager for the construction project; knowing who the project manager was meant that a survey or interview could be conducted to gather information that was not collected or entered into the database for project data (Duff, Robertson, Phillips, & Cooper, 1994) suggests that the nature of safety is related to the behaviors of personnel on site. This became the focus for the survey and an initial set of behavior-based factors were created. A brain-storming session was held with multiple project management members from the construction industry on what factors should be used. This set had a few extra challenges in determining how to measure them in a way that could be used for analysis via an ANN model.

The initial set of behavior-based factors was as follows:

- Location of project manager (directly on site/off site)
- Project manager's engagement in safety
- Project manager's accountability to safety

- Engagement in safety meetings
- Time spent following up actions from meetings
- Time spent with safety personnel
- Perceived schedule pressure
- How the project manager felt the project was running (behind, on time, or ahead of schedule)

Four safety professionals (two male and two female) from the construction company were interviewed to get their thoughts on this list and were asked the following questions to get their opinion on how to measure some of the factors:

1. What factors do they think make a project safe?
2. How would they define safety culture?
3. What are the key contributors to a good safety culture?
4. How would they measure the engagement of project management to safety?
5. How would they measure the accountability of project management to safety?
6. What do they look for when evaluating the quality of a safety meeting?

The results from the interviews with safety professionals had 6 themes in common amongst all four safety professionals.

- Frequency of management on site
- Communication with workers
- Involvement with meetings (the monthly project health and safety (H&S) meeting in particular because it was the project managers responsibility to organize this meeting)
- Time spent on safety related duties

- Mentorship of younger staff
- Site investigation

Using both the list of factors created from the brain-storming session and the themes identified by the safety professionals, a survey of 20 questions was created for the project managers of the projects for which data will be collected.

The questions asked of the project managers were:

1. Were you located on or off site for this project?
    a. If you were located on site, how often did you spend touring the site? (average hours per week)
    b. If you were located off site, how much time did you spend on site? (average hours per week)
2. What percentage of the time did you have a worker with you on formal inspections? (percentage)
3. During site tours (non-formal inspections) how often would you stop and talk to the workers? (percentage)
4. What percentage of all trades on site would attend their monthly project H&S meeting?
5. How much time did they spend on safety related duties? (average hours per week)
6. Were there younger project staff located on site or working on the project?
7. Was there a program, whether it be formal or informal, being implemented for mentoring the younger staff?
8. How often did they check in with their project site safety representative? (number of times per week)
9. How much time would that equate to? (average of hours per week)

10. What type of contract was the job?
11. Did they feel the contract type had an impact on the willingness to spend extra on safety? (this question a knowledge question and not used as a factor)
12. Overall was the project behind schedule, on schedule, or ahead of schedule?
13. Was the original project schedule aggressive or reasonable?
14. Did they investigate the hazards associated with the site conditions prior to the start of the project?
15. Were any special considerations made in the site safety plan for addressing these hazards?
16. Were the special considerations followed up on?
17. What was the safest project they felt they had run? (this question a knowledge question and not used as a factor)
18. What factors contributed to this? (this question a knowledge question and not used as a factor)
19. What did they think was important to having a safe project? (this question a knowledge question and not used as a factor)

The information collected from surveying the project managers was analyzed to create a set of factors that would be used as a result from the survey. Some of the information gathered from the survey was not designed to be part of the ANN model but rather was gathered for the purpose of gaining the perspective and knowledge of the project managers. Some information that was originally intended to be used as a factor in the ANN model was not included because the same answer was given by all participants. The reason for this was that the survey was designed with no particular company in mind. The eliminated questions were related to the site investigation prior to the start of construction. It was a companywide requirement for all projects being constructed by the company, resulting in the same answers from all project managers.

The list of factors used from the survey results were as follows:

- Project manager location
- Hours spent touring the project site
- The percentage of time a worker participated in the inspection process
- Percentage of touring hour that was spent interacting with workers
- The participation percentage to the monthly project H & S meeting of all trades located on site
- Time spent on safety related duties
- Mentoring program
- Number of interactions with project safety professionals in a week
- Time spent with safety professionals in a week
- Contract type (this information belongs to project profile data but was not stored in the project database information)
- Perceived overall schedule pressure of the project
- Perception of reasonability to meet the original schedule.

Collecting Project Data

Using the established list of factors (safety performance measures, safety due diligence factors, project profile factors, and behavioral factors collected from the survey) data was to be collected. The first step was to determine what depth the data was to be collected at (company level, project level, or task level). Since safety is a cause-effect phenomena it was decided that a bottom-top approach would be more appropriate than a top-bottom approach. In construction, processes that take place at the task level and individuals involved would represent the bottom of the hierarchy (see Figure 3.3). Moving up a level would be looking at the construction project that those tasks belong to. The next level in the hierarchy is the company that the project belongs to. One company would have multiple projects. The top level would represent the industry the company belongs to. Multiple companies would belong to the industry, which describes the type of projects being completed by the companies. Starting at the bottom of the hierarchy (i.e. collecting data at the task level) was decided against for the following reasons:

- Data at the task level was probably not collected to the detail required for the neural network (for the contracting company studied, this data did not exist)
- Most likely would have too many activities that would have no safety performance measure to relate to
- Each task would have its own factors, causing complications in analysis

Moving up the hierarchy to the project level was deemed acceptable because there was a sufficient amount of data, consistency within the data, and the data could be related to the safety performance measures.

Hierarchical Representation of Safety

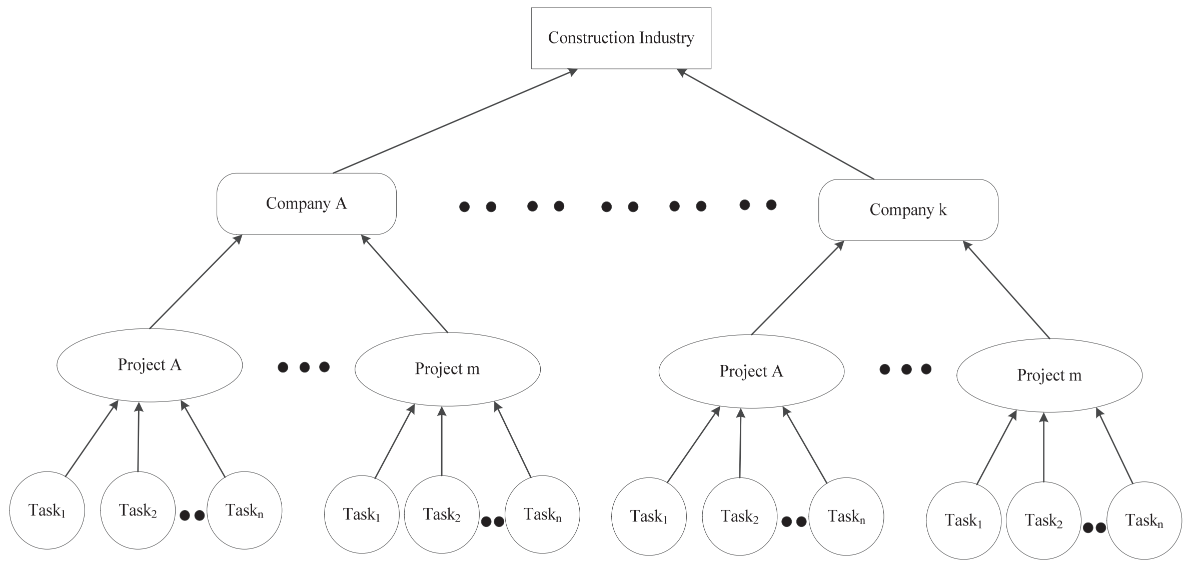


Figure 4.3

In order to have statistical relevance, data would need to be collected from a significant number of projects. A limiting factor to the number of projects that data could be collected from was the size of the construction companies' databases and when they started collecting data related to the list of identified factors. Keeping both the size of the databases and statistical relevance in mind, it was determined that data would be collected from 50 projects. The projects varied in age from less than two years old to starting in 2005, and varied in value from $389,575,500 to $40,000. This number would later be reduced to 45 because of insufficient data points within the discarded project, because project managers could not be contacted, or because of the contractor-owner relationship in the project. The 50 projects were represented by 24 unique project managers. On average, 2 projects would have the same project manager; however, some project managers were the manager for one project only in the data set. The highest number of projects in the data set represented by a single project manager was six. From the original set of 24 project managers, 3 no longer worked for the company or could not be reached, resulting in those projects being removed from the data set.

Once the data was collected from all 50 projects and all 21 project managers that could be reached were surveyed, the data was cleaned and grouped into factors that could be used in the neural network (see Figures 3.4 and 3.5 for a sample of the raw data collected; for the full set of cleaned data refer to Appendix B). The first step in cleaning the data was to determine the hours worked by each trade. The original data was in the form of time cards for each worker on site. The hours had to be summed for each respective trade in order to create a data point for that trade for which project they worked on. The next step was to separate the safety due diligence measures and safety performance measures into groups. The data for these groups was lumped together in a single page for each project. Once the hours for each trade were cleaned, and the safety due diligence measures were separated from the safety performance measures, the survey results were cleaned into a useable form. Table 3.1 summarizes how each of the factors was cleaned. The first step was to determine if the factor was nominal which meant it would be represented by either a 1 or -1. It was done this way to have an equal but opposite representation for answers that were either a yes or no response meaning the magnitude had no pull on the ANN model's analysis of the factors. If the factors were not nominal then they were labeled as a scale factor and could have a range of values representing that factor. The last step was to combine all the various sources of data into one set for each project.

Office: EDM
Project: 000001
Company: Company0101
Start Date: 4/16/2012
End Date: 9/22/2012

Month	TRIR	LTFR	LTI	DL	MA	FA	FAFR	MW	MWD	NM	NMFR	SSHA Com	SSHA Audits	MHR/SSHA	Insp com	A Haz	B Haz	C Haz	Man Hrs
Apr 2012	0.00	0.00	0	0	0	0	0.00	0	0	0	0.00	0	0	0	0	0	0	0	84
May 2012	0.00	0.00	0	0	0	0	0.00	0	0	0	0.00	25	6	34	5	0	0	1	723
Jun 2012	0.00	0.00	0	0	0	0	0.00	0	0	0	0.00	12	5	82	5	0	0	4	827
Jul 2012	0.00	0.00	0	0	0	0	0.00	0	0	0	0.00	18	4	33	5	0	0	0	489
Aug 2012	0.00	0.00	0	0	0	0	0.00	0	0	0	0.00	0	0	0	0	0	0	0	295
Sep 2012	0.00	0.00	0	0	0	0	0.00	0	0	0	0.00	0	0	0	0	0	0	0	73
Total	0.00	0.00	0	0	0	0	0.00	0	0	0	0.00	56	15	55	15	0	0	5	2,491

Figure 4.4

Emp. N	Employee Na	Business	Hours Work	DBA C	Job Typ Description 1
2356	Jon 1	1	1.50	2	CRAFTSMAN V
6377	Jon 2	1	45.00	2	Carpenter
7080	Jon 3	1	105.00	2	Superintendent
8406	Jon 4	1	21.00	2	Carpenter
8962	Jon 5	1	3.00	2	Carpenter
8977	Jon 6	1	2.00	2	CRAFTSMAN IV (C 1)
9899	Jon 7	1	2.00	2	CRAFTSMAN IV (C 1)
10152	Jon 8	1	12.00	2	CRAFTSMAN I
10152	Jon 9	1	27.00	2	CRAFTSMAN IV (C 1)
10332	Jon 10	1	66.00	2	CRAFTSMAN IV (C 3)
2254	Jon 11	1	398.00	1	SUPERVISOR II
2356	Jon 12	1	111.00	1	CRAFTSMAN V
2526	Jon 13	1	40.00	1	SUPERVISOR III
2921	Jon 14	1	18.00	1	CRAFTSMAN III
2996	Jon 15	1	189.00	1	CRAFTSMAN IV (C 4)
3825	Jon 16	1	4.00	1	CRAFTSMAN III
6377	Jon 17	1	823.00	1	Carpenter
7057	Jon 18	1	48.00	1	SUPERVISOR I
7080	Jon 19	1	1479.00	1	Superintendent
7097	Jon 20	1	55.50	1	Carpenter
7413	Jon 21	1	247.00	1	Carpenter
7605	Jon 22	1	14.00	1	CRAFTSMAN II
8406	Jon 23	1	766.00	1	Carpenter
8513	Jon 24	1	52.00	1	CRAFTSMAN II
8962	Jon 25	1	320.00	1	Carpenter
8977	Jon 26	1	80.00	1	CRAFTSMAN IV (C 1)
9141	Jon 27	1	17.00	1	CRAFTSMAN II
9208	Jon 28	1	46.00	1	CRAFTSMAN II
9592	Jon 29	1	34.00	1	CRAFTSMAN IV (C 4)
9777	Jon 30	1	16.00	1	CRAFTSMAN II
9813	Jon 31	1	27.00	1	CRAFTSMAN V
9899	Jon 32	1	22.00	1	CRAFTSMAN IV (C 1)
9914	Jon 33	1	39.00	1	CRAFTSMAN II
10043	Jon 34	1	45.00	1	CRAFTSMAN II
10120	Jon 35	1	44.00	1	CRAFTSMAN II
10123	Jon 36	1	35.00	1	Carpenter
10124	Jon 37	1	10.00	1	CRAFTSMAN IV (C 1)
10152	Jon 38	1	618.00	1	CRAFTSMAN I
10152	Jon 39	1	466.00	1	CRAFTSMAN IV (C 1)
10310	Jon 40	1	132.00	1	CRAFTSMAN II
10332	Jon 41	1	816.00	1	CRAFTSMAN IV (C 3)
10396	Jon 42	1	44.00	1	CRAFTSMAN II
10477	Jon 43	1	85.00	1	CRAFTSMAN II
10479	Jon 44	1	44.00	1	CRAFTSMAN II
10586	Jon 45	1	33.00	1	Carpenter

Figure 4.5

Factor	**Measure**	**Range of Possible Values**
ProjectManagerLocation	Nominal	1,-1
PMTouringHRS	Scale	0 – +∞
WorkerInspectionPercentage	Scale	0 – 100
WorkerInteractionPercentage	Scale	0 – 100
JHandSMeetingRepresentation	Scale	0 – 100
TimeOnSafetyDuties	Scale	0 – +∞
Mentoring	Nominal	1,-1
NumberOfSafetyInteractions	Nominal	1,-1
HoursOfSafetyInteractions	Nominal	1,-1
TypeOfContractP3	Nominal	1,-1
TypeOfContractCMAtRisk	Nominal	1,-1
TypeOfContractLumpSum	Nominal	1,-1
TypeOfContractCostPlus	Nominal	1,-1
TypeOfContractPurchaseOrder	Nominal	1,-1
TypeOfContractUnitPrice	Nominal	1,-1

ScheduleOn	Nominal	1,-1
ScheduleAhead	Nominal	1,-1
ScheduleBehind	Nominal	1,-1
SchedulePressureReasonable	Nominal	1,-1

Table 4.1

Limitations of Data

The data used in this study did have their limitations. The data only came from one company, which means trends between companies could not be represented, only trends between the different projects within one company. The reason only one company was used in the study was to eliminate inconstancy of factors between companies. Since every company has their own standards and practices, a factor belonging to company A may not equate to the same factor for company B. In order to simplify the analysis, only one company was used.

Another limitation of the data is the small number of safety incidents amongst all the projects. Many of the projects had no recordable safety incidents, which meant many of the projects in the data set had very little variance in the safety performance measures. This can be contributed to two reasons. The goal of the construction company studied is to have zero incidents on all projects. This study attempted to capture these, but it also meant that many of the projects would have similar safety performance measures. The other reason is the classification of incidents does not capture all safety incidents that occur on site. For example, if a worker cuts his/her finger but returns to work the same or next day, this is not recorded as an incident. Any minor incident that occurs on a site would not be recorded, nor could it be used in this study. Any incidents that almost occurred or were just barely avoided (near misses) were not used. This was due to the inconstancy of this measure; often many more near misses occur than are recorded so it would be difficult to get an accurate measure between projects.

The data collected could not describe the individual workers to the desired level of detail. Since most of the data related to the individual workers was not available, it was not possible to get an accurate measure for experience and age of workers on site. The data could not describe the physical layout and congestion of the site. It would have been useful to have a measure for both congestion and layout (how many floors, square footage, open site or building on existing structure) of the site. The surveys were able to collect information on the schedule pressures, but due to the sensitive nature, the cost pressures of the projects were not available for use. Another limitation to the survey data was the information was based on the memory of project managers. This limits the accuracy of the data to how well the project manager remembers the project. The responses from the individuals had to be represented as a number or a yes/no and looked at over the entire project. This was difficult for the project managers since the life cycle of a project has many different phases, which would yield different answers depending on the phase. They had to use their experience and judgement to answer the questions from the overall project aspect. This meant there would be some variance in answers between project managers since every person had different experiences and their own biases.

Collecting the following data could have helped to reduce the limitations of the data, had they been available for collection:

- Years of experience for each individual worker

- Age of each individual worker
- Workers' perceptions of the schedule pressure, cost pressures, and company safety culture
- Layout of site
- Congestion of site
- Weather conditions during incidents
- Information on the minor, non-recorded incidents
- Cost pressure of the project
- Amount of money spent on safety for the project
    - Amount for training
    - Amount for personal protection equipment (PPE)
    - Amount for safety personal

5. Artificial Neural Network Analysis

Introduction

The goal of the project was to determine the factors that had the greatest impact on the safety performance of a construction project. It has been argued that no meaningful analysis into safety in construction can be done without the collection of data (Fang, Huang, & Hinze, 2004). This can be attributed to the fact that safety is a complex and difficult-to-define phenomena for which analytical/mathematical equations do not exist. This study is no exception, and this is why numeric data modeling techniques are required to analyze the data collected in this study. An

ANN was chosen as the tool to use because it is effective at analyzing data that has a complex relationship between variables and for data that is noisy with no applicable theory (Haykin, 1999).

In this chapter, an introduction to artificial neural networks will be discussed, the creation of a feed-forward back propagating neural network using the collected data discussed in the previous chapter, the configurations of data used with that model, and potential uses of the model.

Artificial Neural Networks

There are different types of artificial neural networks that use various types of algorithms to analyze the inputs and outputs used within the model. Some of the most common types of artificial neural networks are feed forward, radial basis function, and Kohoen self-organizing networks. A basic neural network consists of three main layers. The first is the input layer. This layer consists of a set of nodes created by using known data that has some undetermined influence over a separate layer of data, referred to as the output layer. This layer also consists of a set of known data that is somehow influenced by the input layer. The last layer is called the hidden layer. This layer can consist of multiple layers all performing a similar function. These layers use processing elements (PE) to receive input information from either the input layer nodes or other PE. The PE then delivers an output which is then compared to the data in the output layer. Between these layers are connections that have a weight associated with them. The way networks function is by taking information from the input layer, transferring it to the hidden layer via links that each have a weight, having the PE process the information and delivering an output. The network then compares this information and checks the error between the output information from the PE and the data in the output layer. It then will adjust the weights of the links and repeat this process until the error between the output information of the PE is within an acceptable range of the output layer data. The feed forward, radial basis function and Kohoen self-organizing networks differ from each other in terms of the direction of the data flow and how the network will calculate the relationships between the inputs and outputs. The feed forward was the chosen type as it is the simplest to use. Feed forward artificial neural networks utilize a concept that the outputs are equal to the summation of inputs that have had a weight factor applied to them. See the following equation.

$$PE_{input}(\text{Current Layer}) = \sum_{i=1}^{n} PE_{output[i]}(\text{Previous Layer}) \times \textit{Weighting of link}_i$$

The networks use a special function referred to as the activation function to pass the information forward through the network starting at the input layer, moving through the hidden layer(s), and finally reaching the output layer. Refer to the following equation.

$$PE_{output}(\text{Current Layer}) = f(PE_{input}, \textit{Transfer Function})$$

There are two common transfer functions used with feed-forward artificial neural networks. The sigmoid transfer function and hyperbolic tangent function. The sigmoid transfer function has been extensively used for the majority of construction applications of artificial neural networks and produced reasonable results (Lu, 2000; Portas, 1996).The difference between transfer functions is the sigmoid transfer function will output a valve between 0 and 1, whereas the hyperbolic tangent function will output a value between -1 and 1.

$$f(x) = \frac{1}{1+e^{-x}} \qquad f(x) = \tanh(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}}$$

Sigmoid transfer function Hyperbolic tangent function

Both transfer functions serve the same purpose. Figure 4.1 shows that each node within the hidden layer(s) is connected by multiple nodes in the input layer. The transfer function will take the summation of products between the inputs and their respective weights. This value is what both functions use as x, and then will create a single value to pass to the next layer. A bias node is also included within the calculation, and is connected to all the nodes within in the network. The purpose of the node is to shift the transfer function, ensuring that it is not symmetrical around the origin. This value of the bias node is set to 1 or -1, with the value of the weights between nodes being a value between -1 and 1. The transfer function will take the single value (a function of the previous input values and bias node values) and its weight to become the new input value for the next layer within the model. The transfer function then repeats the calculation moving forward through the network until it reaches the output layer. The final value that has reached the output layer is then compared to the values that are in the output layer (the information provided by the network user). An error calculation is computed between the data in the output layer and the value of data that was fed forward through the network (predicted output value). If this error is not within an acceptable tolerance, the network will back propagate, adjusting the weights. This process will repeat until the error between the predicted outputs and the existing outputs are within an acceptable error range.

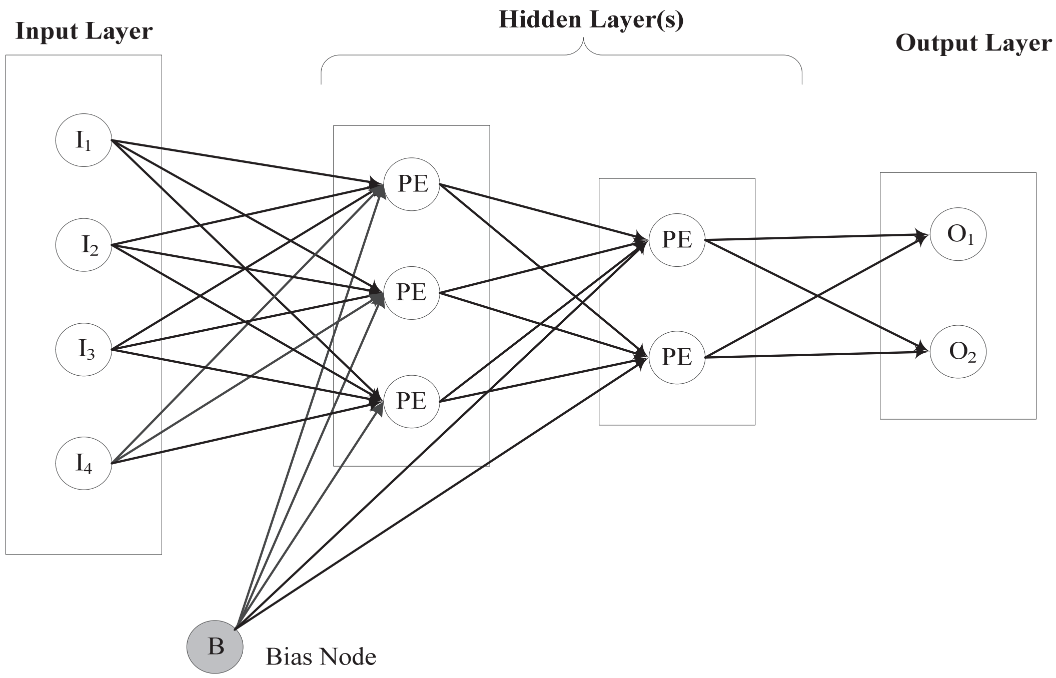


Figure 5.1

The network uses the following equation to adjust the weights as it back propagates through the network:

$$Weight_{new} = Weight_{old} + \alpha\delta_j X_i$$

where the weight in question is the weight connecting nodes *i* and *j*, δ_j is the error at node *j*, X_i is the value from the transfer function at node *i*, and α is the learning rate or learning coefficient. This is a constant value used to dictate the rate or speed at which the network will train.

Artificial neural networks require the data in which the network will model to be split into two sets. A training set and a testing set. The training set will go through the process mentioned above, and will be used to develop the weights for which the model will use; the training set is mutually exclusive from the testing set. The testing set is used to validate the weights determined from the training data by using the inputs to predict an output using the weights from the trained network and comparing to the output values of the testing set. There is no set rule dictating what percentage of the data should be used for training and what portion should be used for testing, but common practice is to split the data into 70% for training and 30% for testing.

The objectives of the ANN model used in this study were to:

1. Construct a neural network to assist in the prediction of safety incidents
2. Identify important factors that have the biggest impact on the safety performance of a construction project

Determining the proper configuration of factors was an iterative process. Due to the iterative nature of artificial neural networks, many possible solutions exist, and some researchers have experimented using multiple configurations of a model to see possible reduction in error. The configurations were implemented incrementally in order to accurately see the effect of the changes made in each configuration on the results.

The implementation of each configuration followed the same steps as developing the model:

1. Organized collected data into each respective project
2. Transformed data into neural network inputs and outputs
3. Created training set (roughly 70% of the data)
4. Created testing set (roughly 30% of the data)
5. Created neural network using transformed data in step 2
6. Trained data using training set
7. Once network had its weights within an acceptable error level, used testing set to validate data

The results from the analysis were a set of factors that have had their impact on the outputs determined. The lists will be ranked in highest importance (100%) to lowest (0%) importance with respect to their influence on the output data.

Once the validated artificial neural networks were created, an application could be developed to predict incidents on a construction project. This application would use the already created networks as a framework to predict the incidents that would occur on a new project based on new inputs provided.

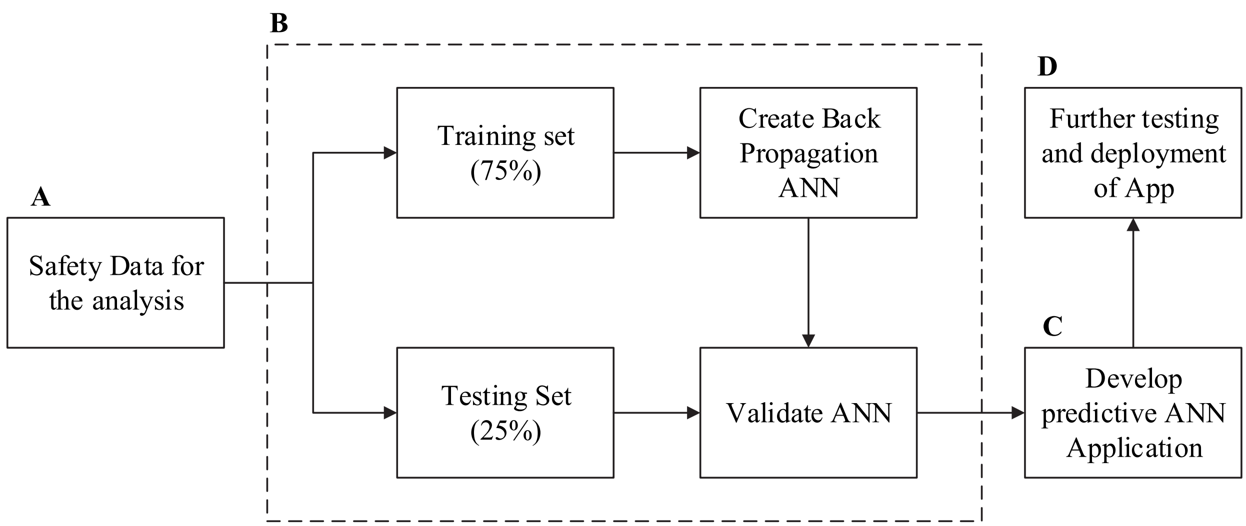


Figure 5.2

The development can be broken down into 4 sections. Section A is the collection of data discussed in the previous chapter which was used for the creation of the ANN. Section B refers to the development and validation of the ANN model using the set of factors created in section A. Section C referrers to the application developed to predict incidents on future projects. Section D refers to the path moving forward after this study. Sections B and C will be discussed in this chapter.

Creation of Feed Forward-Backward Neural Network

There is a variety of software available that uses artificial neural networks to analyze sets of data. The more common programs in use are Weka, Statistical Pack for Social Scientists (SPSS), Neuro Shell, and MATLAB. SPSS was used in the study due to availability and familiarity with the program.

The first step in creating the ANN model was to first do a linear regression analysis on the factors to see if any could be eliminated prior to creation of the model.

Figure 4.3 shows that increasing the number of overtime hours would decrease the number of category C hazards. This would not match reality, as working more overtime would increase the working hours of the project; if the workings hours of the project are increased, one would expect the number of hazards to increase with time. This was most likely due to the complex nature of safety data and suggests the factors should not have been analyzed in isolation.

Correlation between Overtime and the Number of Category C Hazards

		OT	OCHazards
OT	Pearson Correlation	1	-.057
	Sig. (2-tailed)		.710
	N	45	45
OCHazards	Pearson Correlation	-.057	1
	Sig. (2-tailed)	.710	
	N	45	45

Figure 5.3

The results from Figure 4.4 show that having an increase in overtime hours would reduce the number of first aids. This would not make sense in reality, as working overtime causes workers to be more fatigued and will increase their chances of having an injury. This reiterates the complex nature of safety data, and reinforces that the factors should not be looked at in isolation.

Correlation between Overtime and the Number of First Aids

		OFirstAids	OT
OFirstAids	Pearson Correlation	1	-.019
	Sig. (2-tailed)		.901
	N	45	45
OT	Pearson Correlation	-.019	1
	Sig. (2-tailed)	.901	
	N	45	45

Figure 5.4

The results from Figure 4.5 show that increasing the number of inspections would increase the number of category C hazards. This would make sense in reality, because the goals of the inspections were to identify and control hazards; having more inspections would ultimately identify more hazards. This supports the notion that safety data is very complex; when looking at some factors in isolation, this trend makes sense while others did not.

Correlation between Number of Inspections and the Number of Category C Hazards

		OCHazards	NumberInspections
OCHazards	Pearson Correlation	1	.989**
	Sig. (2-tailed)		.000
	N	45	45
NumberInspections	Pearson Correlation	.989**	1
	Sig. (2-tailed)	.000	
	N	45	45

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 5.5

The linear correlation study results reinforced the need to use a neural network. A model was developed in SPSS. The first step to developing the model was to input the collected data into 3 sections within SPSS, the dependent variables, the factors, and the covariates. The dependent variables are the outputs for the model, or in the case of this study, the safety performance measures. The data in this set is somehow related to the data belonging to both the factors and covariates. Both the factors and covariates can be described as the predictor variables. The data belonging to these categories were used to predict the data found in the dependent variables section. Covariates are represented by data that have a quantitative relationship with the dependant variables that can be fit within a scale. In the model used in this study, the covariates were the project profile factors, as they were all numeric values that could be placed on a scale. For example, overtime hours. This factor was the total hours worked past regular working hours. A higher number meant more overtime was worked. Factors within the SPSS model structure can be described as data whose values can be represented by a number of different values. In this study, the responses from the surveys were used as the factors because they were not easily fit on a scale. For example, whether a project finished behind, on schedule, or ahead of schedule would not easily fit on a scale. Figure 4.6 is a screen shot summarizing the inputting of variables within SPSS.

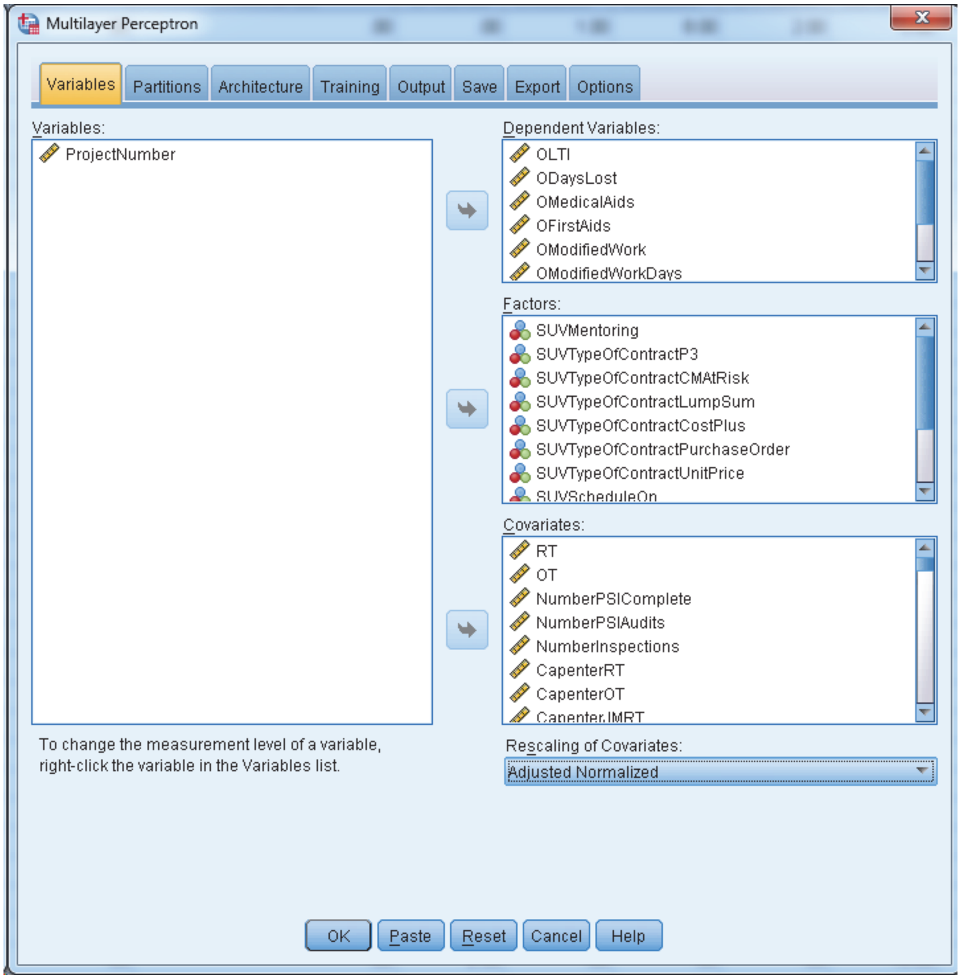


Figure 5.6

The next step in developing the ANN was to partition the data into training and testing sets. In SPSS, you have the choice manually assign which data you would like to use for training and which data you would like to use for testing. The other option was to have SPSS randomly assign the data based on a set of parameters which are decided by the user. If the random selection option was chosen, SPSS required the user to define how to split the data based by percentage into three groups. The first group was the training group; this was the percentage of the data to be used to train the ANN model. The second group was the testing group; this was the percentage of the data to be used to test the trained ANN model. The third group was the holdout group; this was the percentage of the data to be left out of the model. For the model used in this study, the option to randomly partition the data was selected; 70% of the data was used to train the model, 30% of the data was used to test the model, and no data was withheld from the model. Figure 4.7 is a screenshot showing how the model was partitioned.

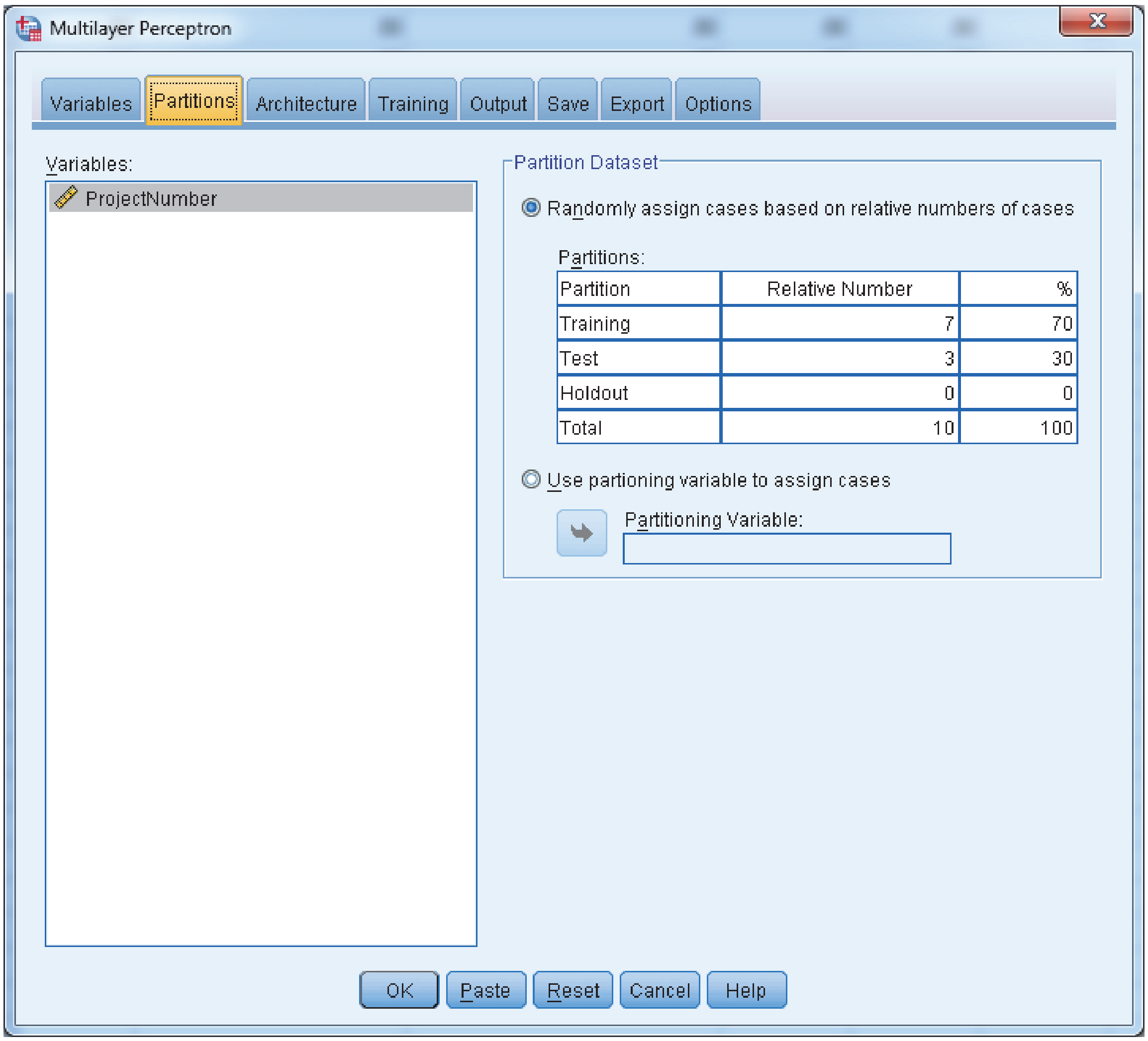


Figure 5.7

After the partitioning information was selected, the architecture of the model needed to be input. SPSS has two options for creating the architecture of the model. The first is an automatic selection of architecture selected by SPSS. SPSS will select the "best" architecture based on a specified minimum and maximum number of units (or nodes) within the hidden layer. A single layer is used with the automatic selection of architecture. In this study, a custom architecture was created.

The first step in creating a custom architecture was to decide between one or two hidden layers. For most studies, one layer is sufficient and adding a second hidden layer is used in highly complex models. In this study a single layer was selected. Although the relationship between the factors may be complex, they are being related to one common theme of safety. If this study was looking at the impact of the factors on safety, quality, and productivity for example, then an additional layer may have been considered.

After determining the number of hidden layers, the number of units or nodes needed to be specified. There is no general rule on how many nodes to have within the network. In this study, 5 nodes were selected because multiple configurations of the model were going to be used having between 62 and 21 input factors. In order to have consistency between configurations, the same architecture would need to be used between all three configurations. Selecting 5 nodes was a happy medium between having too few nodes for 62 inputs and having too many nodes for 21 inputs.

Once the number of nodes was determined, the type of activation function needed to be selected. SPSS uses two different types of activation functions: hyperbolic tangent function and the sigmoid function. The activation function's purpose is to link the weighted sum of the nodes connected to the previous layer to the next layer. The hyperbolic tangent function will create a weight between -1 and 1, whereas the sigmoid function will create weight between 0 and 1. This sigmoid function was selected to keep the impact/importance of the factors between 0 and 100%. This was chosen for the output layer for the same reasons.

The last step in determining the architecture of the ANN model was choosing a rescaling method. This was used to put all the scale factors onto a comparable scale. The standardized method subtracts the mean value of variables and divides by the standard deviation. The normalized method rescaling method places the values between 0 and 1. The adjusted normalized function is similar to the normalized method other than it places the values between -1 and 1. Since the sigmoid activation function was used, the normalized function was used as default. Figure 4.8 is a screen shot for the architecture setup of the model.

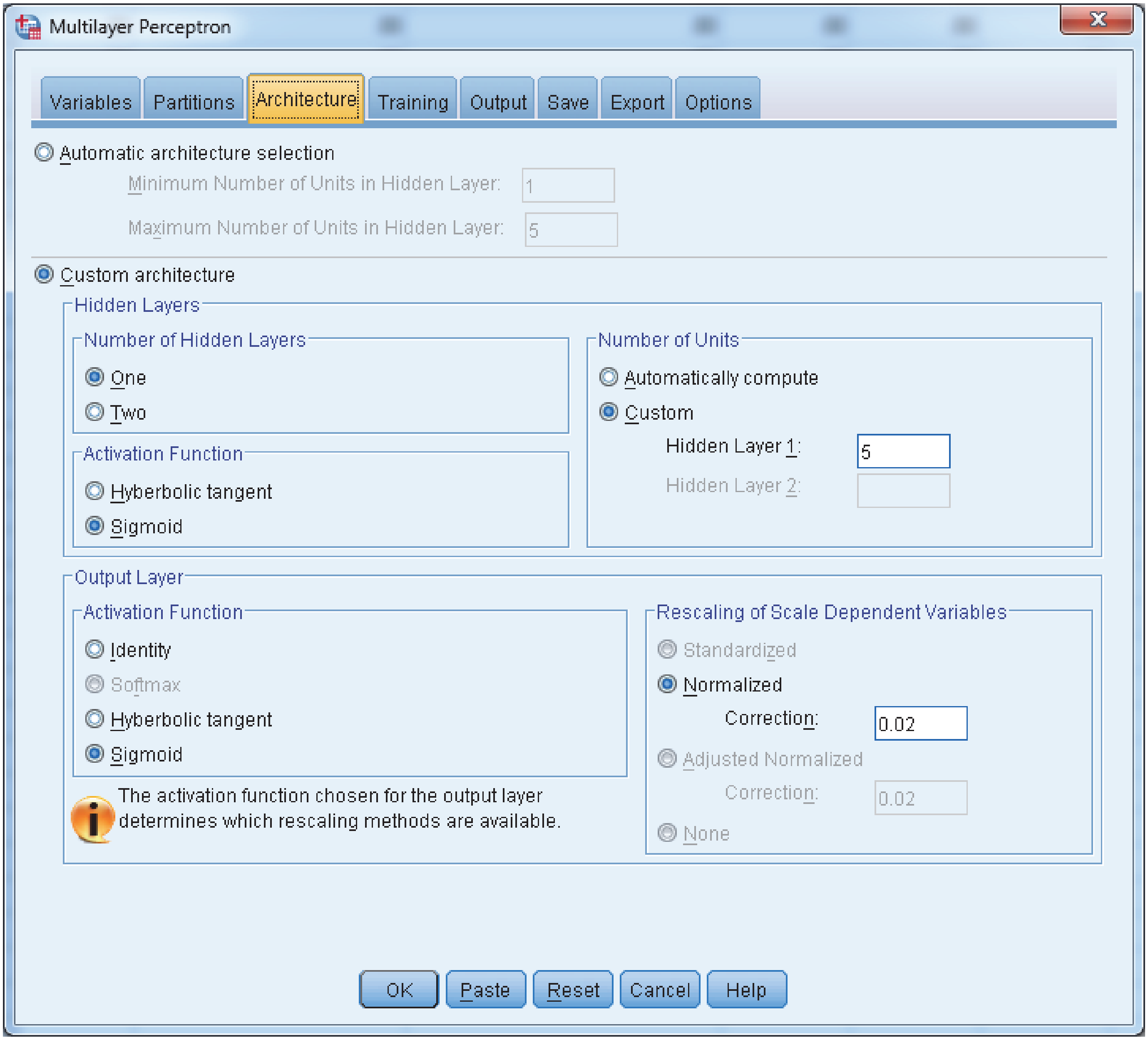

Multilayer Perceptron
Variables
Partitions
Architecture
Training
Output
Save
Export
Options
Automatic architecture selection
Minimum Number of Units in Hidden Layer:
1
Maximum Number of Units in Hidden Layer:
5
Custom architecture
Hidden Layers
Number of Hidden Layers
One
Two
Activation Function
Hyberbolic tangent
Sigmoid
Number of Units
Automatically compute
Custom
Hidden Layer 1:
5
Hidden Layer 2:
Output Layer
Activation Function
Identity
Softmax
Hyberbolic tangent
Sigmoid
The activation function chosen for the output layer determines which rescaling methods are available.
Rescaling of Scale Dependent Variables
Standardized
Normalized
Correction:
0.02
Adjusted Normalized
Correction:
0.02
None
OK
Paste
Reset
Cancel
Help

Figure 5.8

The next step was to set up the training section in SPSS. SPSS allows for three types of training: batch, online and mini-batch. Batch training updates the weights only after passing through all the training data records. It uses information from all records in the training data set. This was the training type selected in this study because it is the most useful for smaller data sets, which is the scenario of this study. Online training used the data from one record at a time and updates the weights after each one. It is the better choice for large sets of data. Mini-batch combines both batch and online by splitting the data into smaller but equal-sized groups and using the data from that group only, updates the weights and moves to the next group. There was the option to manually select the group size or let SPSS decide.

Following the selection of the training type, an optimization algorithm needs to be selected. The optimization algorithm is what SPSS uses to estimate the weights. SPSS utilizes two different methods: scaled conjugate gradient and gradient descent. This study used the gradient descent as the scaled conjugate gradient was more restrictive about the data that can be used with it.

The last step in setting up the training for the model in SPSS was to adjust the parameters of the optimization algorithm. Since the model in this study used the gradient descent optimization algorithm, four parameters were required to be adjusted: initial learning rate, lower boundary of learning rate, momentum, and learning rate reduction. The initial learning rate was the initial value for the gradient descent algorithm, the higher the value the faster the training will occur. This model may become unstable if a value is selected that is too high, because it causes the function to reach a minimum before sufficient learning has been completed. The lower boundary of learning rate online applies to online and mini-batch training and was not used in this study. The momentum parameter is added for the prevention of instability of the model caused by an overly high learning rate value being selected. The learning rate reduction is used for online or mini-batch training only. The default values were selected for use in this study as these parameters are only changed if the network has issues estimating the weights. Figure 4.9 shows a screen shot of the training tab for the model created in SPSS.

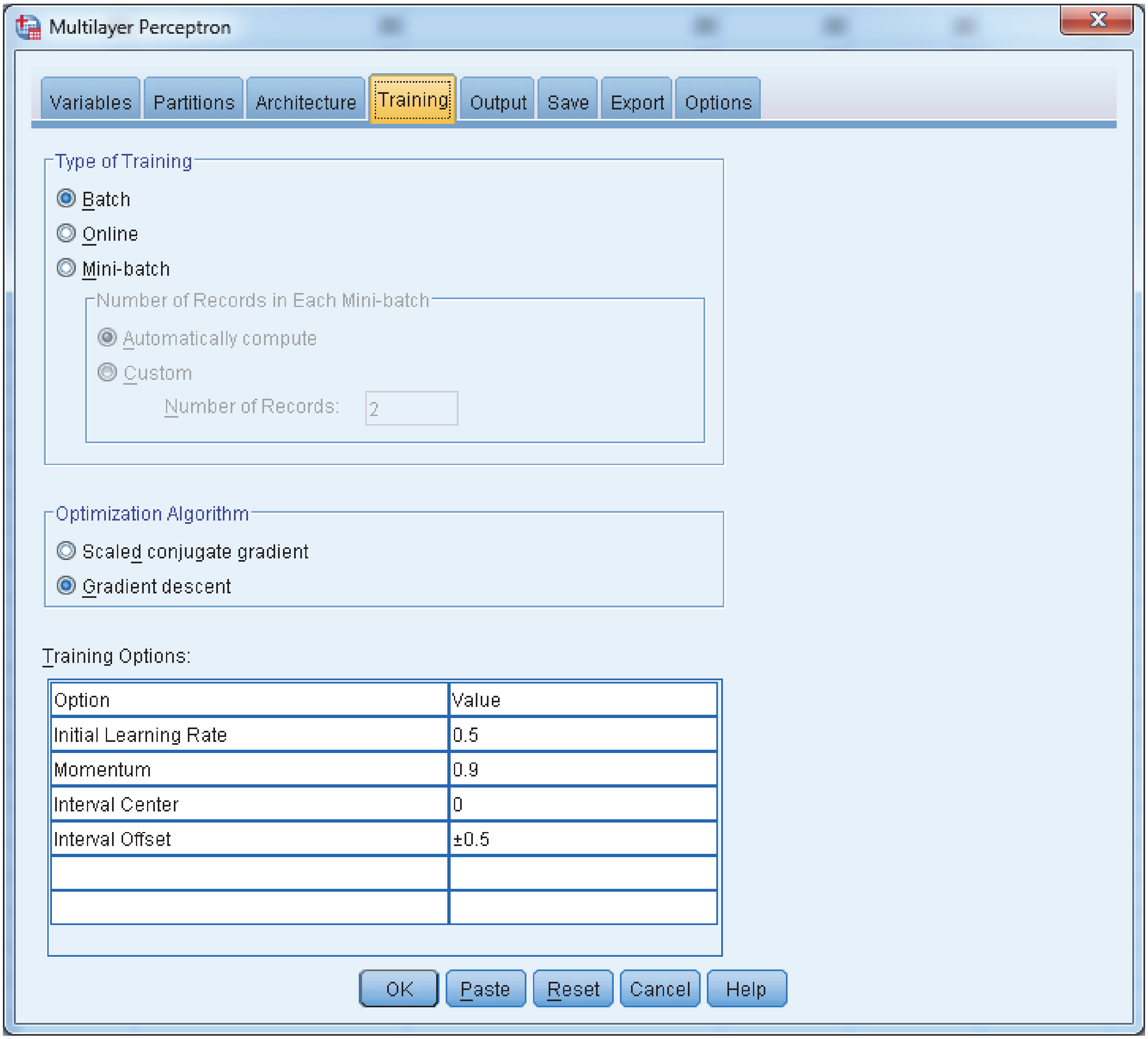


Figure 5.9

After setting up the training tab for the model, the output tab needed to be completed. The first section of the output tab is the network structure. This section describes the summary information of the network. Selecting the description box will display the following information from the ANN: the dependent variables, number of input and output units, number of hidden layers and units, and activation functions. Selecting the diagram box will display a visual representation of the model. SPSS cannot adjust the resolution of the image, so as the number of inputs and outputs increases, the visual clarity of the image is decreased. Selecting the synaptic weight box will display the weights of the coefficients for the relationships between layers within the model.

The second section on the output tab is the network performance information. This section is used for selecting what results will be displayed from the model. The information from the network performance is crucial to determining whether the model is acceptable or not. The model summary box, if selected, will display the error, the relative error or percentage of incorrect predictions, the rule that was used to stop training, and the training time. In this model, the error is sum of squares error since the sigmoid activation function was used. The classification of results will display a classification table for each category of dependent variables. The table will give the number of cases classified correctly or incorrectly for each dependent variable category. The ROC curve and Lift chart were not used in this study. Selecting predicted by observed chart or residual by predicted chart will display a chart of each respective type for every input in the model.

Selecting the case processing summary will display a table that summarizes the number of cases included and excluded in the analysis split into training, testing and hold out sample.

The independent variable importance analysis box, when selected, will perform a sensitivity analysis, which calculates the importance of each input on determining the neural network.

Figure 4.10 was a screen shot of the output tab used in this study's ANN model.

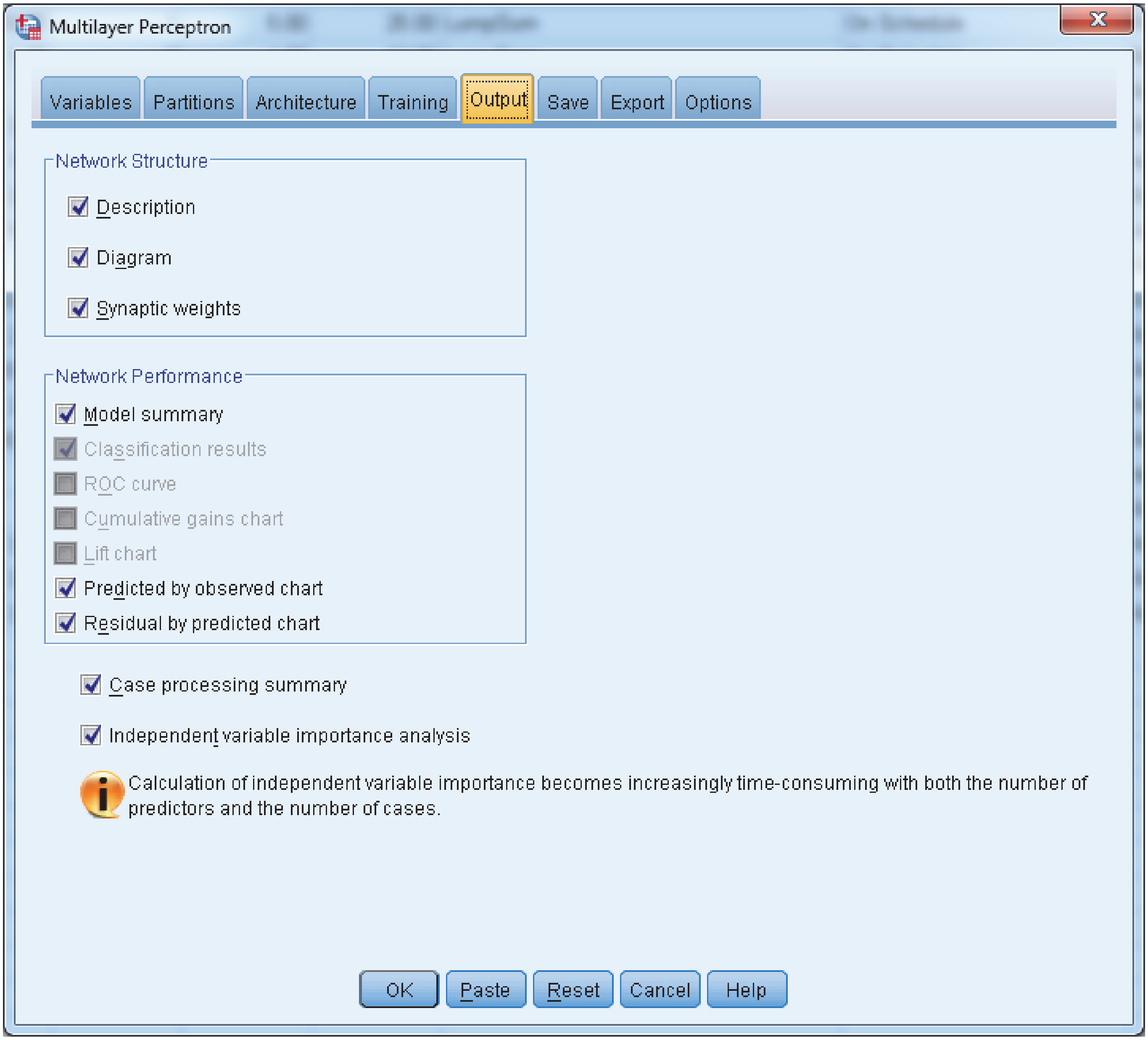


Figure 5.10

The save tab in the SPSS model setup had no impact on the analysis of the study as it talks about the saving of variables within SPSS. It gives you the option to save the predicted value for each of the inputs which would save time for future uses of the model. SPSS also lets the user save the predicted pseudo-probabilities for each dependent variable. Figure 4.11 shows the screen tab for the SPSS model setup for this study

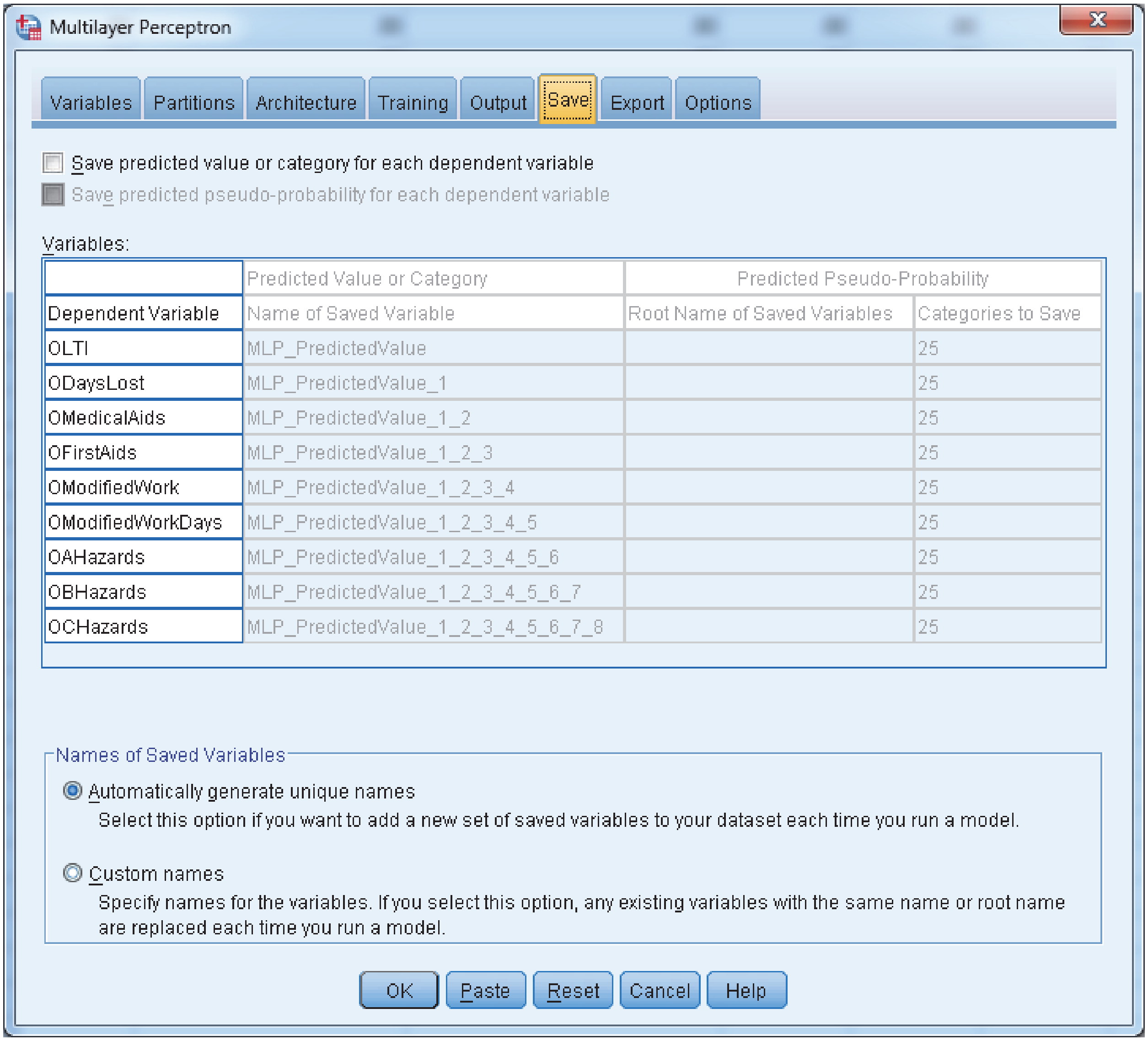


Figure 5.11

Much like the save tab, the export tab for the initial setup of the SPSS model had no impact on the analysis of the data. SPSS gives the user the option to export the weights to an XML file. Figure 4.12 is screen shot of this study's export tab in the model setup

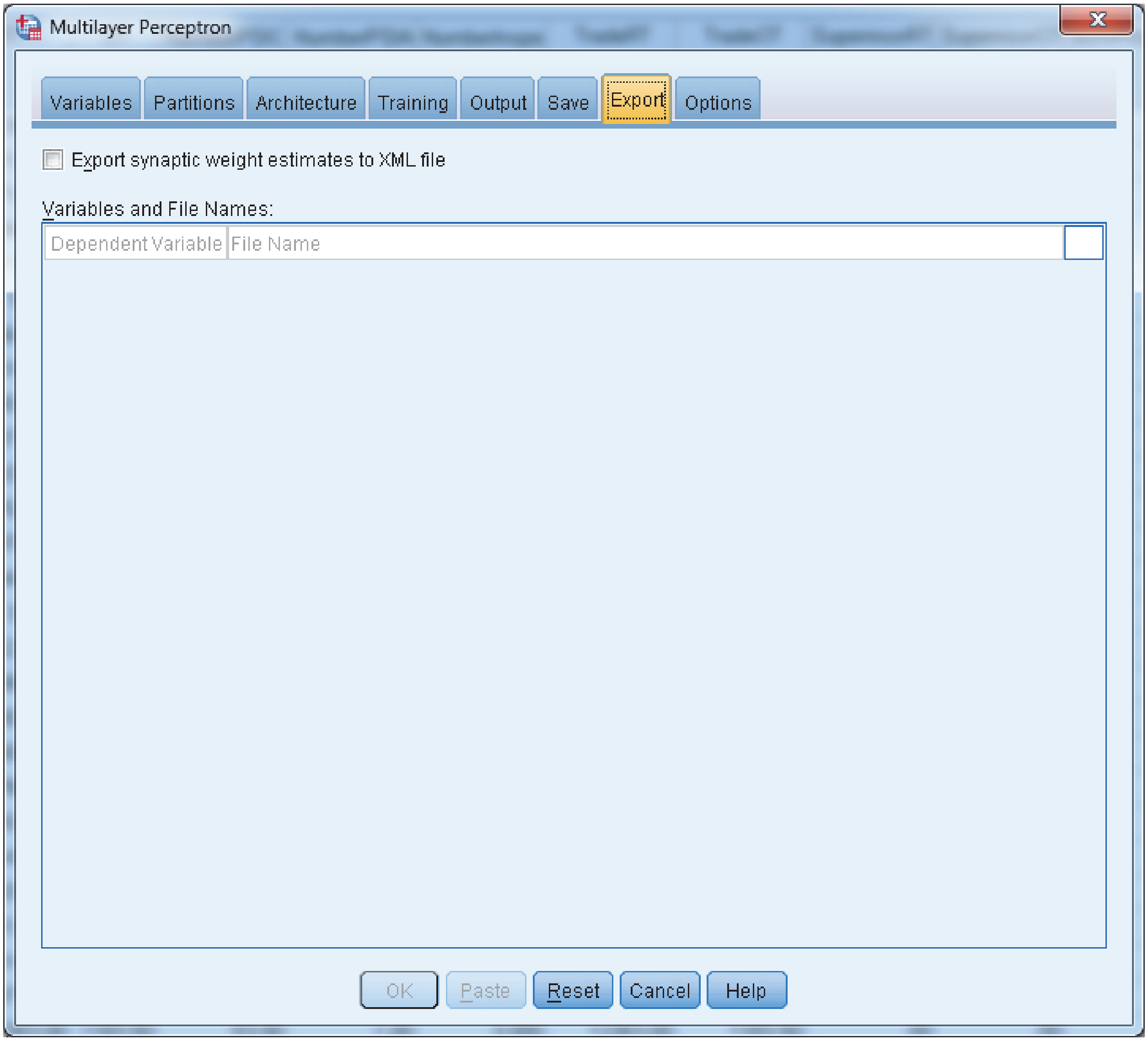


Figure 5.12

The last section that requires input to set up an ANN model within SPSS is the options tab. The user-missing values section has the option to include or excluded cases that have missing values from the analysis. In this study, the option to exclude cases with missing data was chosen.

The stopping rules provide the information the model requires to know when it should stop training the network. The network will always train through at least one data pass but then can be stopped by the rules defined in this section. The first rule that is checked is the number of steps the model is allowed to carry forward with no decreases in error. Once this number of steps is reached, the model stops training the data. The second stop rule is a maximum length of training time. Once this duration is reached the model will come to a stop. The third rule is the maximum number of steps. Reaching this value will cause the model to stop. SPSS gives the user the option to specify a custom number or to have the model automatically assign this number. The last stopping rule is the minimum and maximum relative change in training error. Once again, if either of these values is reached, the model will halt the training of data. In this study, 1 step was allowed with a decrease in error or a maximum of 15 minutes. Figure 4.13 is a screen shot from the options tab used in this model.

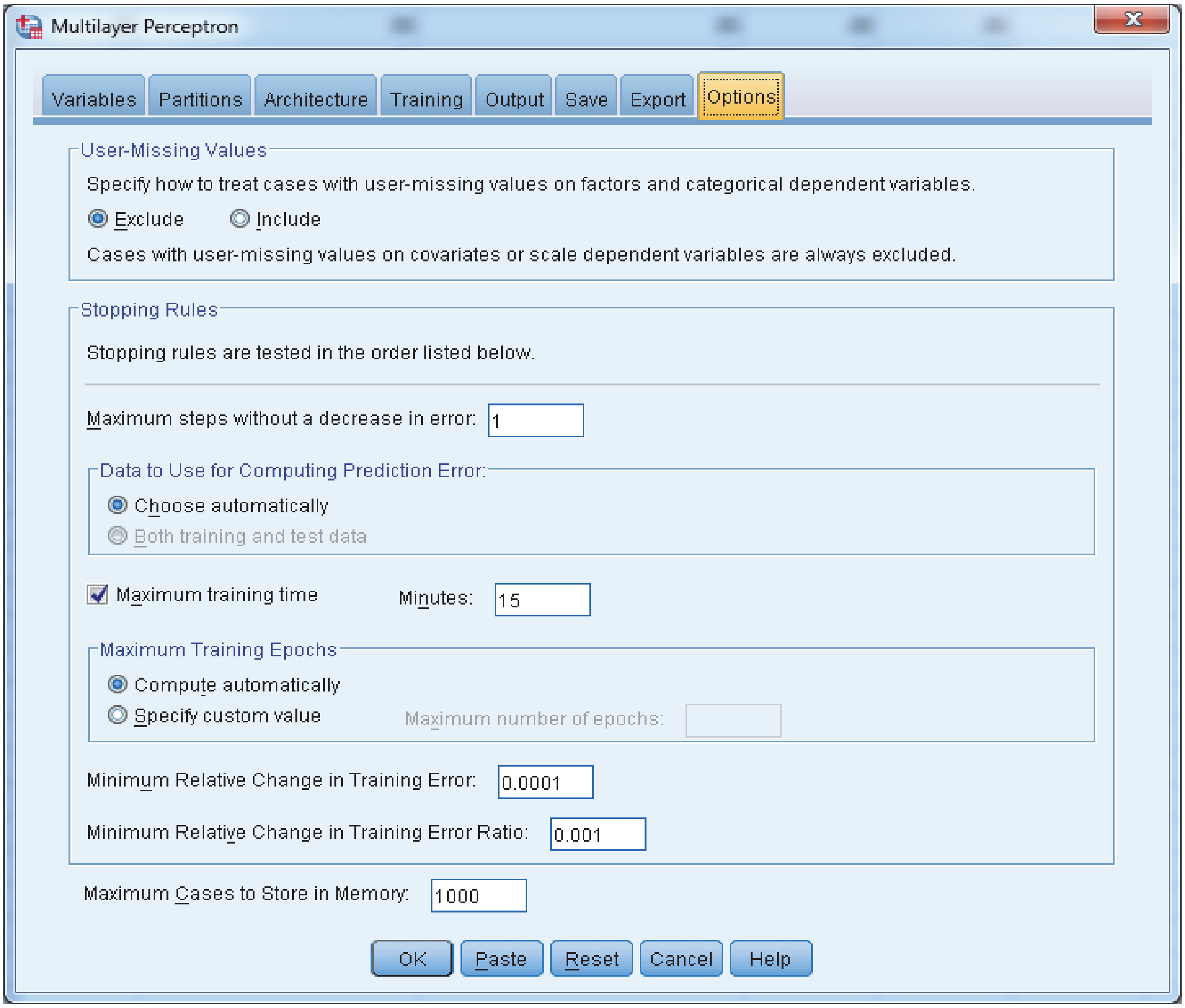


Figure 5.13

Configurations of Ann Model

Three unique model configurations were tested. All three configurations used the data collected from the project data sources or the surveys discussed in the previous chapter. What made each configuration different was that for each case, certain factors were combined together to create a new factor. The purpose behind creating three configurations or versions of the model was to see what factors were consistently showing a high impact/importance on the safety performance of construction projects. The purpose was to see how reducing the number of points or using less noisy data would affect the ANN model.

Configuration 1

The first configuration of the model used took all the factors collected and input them into the model. None of the factors were combined in any way. Any of the trades that had their hours collected by categorizing them into a skill level were left in their respective skill level categories. For example, the craftsman trade had an input for craftsman I, craftsman II, craftsman III, craftsman IV, etc., and these were each represented by a single output. Table 4.1 lists all the inputs and outputs used for this configuration of the model. Throughout all three model configurations, the set outputs used remained constant and no changes were made to it. Figure 4.14 is a graphical representation of the model. Refer to Appendix C for the weights of the model.

Field/Attribute	**Field Type**	**Measure**	**Role in ANN**
ProjectNumber	Numeric	Scale	Input
RT	Numeric	Scale	Input
OT	Numeric	Scale	Input
Number SSHA Complete	Numeric	Scale	Input
Number SSHA Audits	Numeric	Scale	Input
NumberInspections	Numeric	Scale	Input
CapenterRT	Numeric	Scale	Input

CapenterOT	Numeric	Scale	Input
CapenterJMRT	Numeric	Scale	Input
CapenterJMOT	Numeric	Scale	Input
CapenterFMRT	Numeric	Scale	Input
CapenterFMOT	Numeric	Scale	Input
CementFinisherRT	Numeric	Scale	Input
CementFinisherOT	Numeric	Scale	Input
ConcreteFinisherRT	Numeric	Scale	Input
ConcreteFinisherOT	Numeric	Scale	Input
SafetyOfficerRT	Numeric	Scale	Input
SafetyOfficerOT	Numeric	Scale	Input
CraneOperatorRT	Numeric	Scale	Input
CraneOperatorOT	Numeric	Scale	Input
Craftsman1RT	Numeric	Scale	Input
Craftsman1OT	Numeric	Scale	Input
Craftsman2RT	Numeric	Scale	Input
Craftsman2OT	Numeric	Scale	Input
Craftsman3RT	Numeric	Scale	Input
Craftsman3OT	Numeric	Scale	Input
Craftsman3F1RT	Numeric	Scale	Input
Craftsman3F1OT	Numeric	Scale	Input
Craftsman4C1RT	Numeric	Scale	Input
Craftsman4C1OT	Numeric	Scale	Input

Craftsman4C2RT	Numeric	Scale	Input
Craftsman4C2OT	Numeric	Scale	Input
Craftsman4C3RT	Numeric	Scale	Input
Craftsman4C3OT	Numeric	Scale	Input
Craftsman4C4RT	Numeric	Scale	Input
Craftsman4C4OT	Numeric	Scale	Input
Craftsman5RT	Numeric	Scale	Input
Craftsman5OT	Numeric	Scale	Input
Craftsman6RT	Numeric	Scale	Input
Craftsman6OT	Numeric	Scale	Input
ForemanRT	Numeric	Scale	Input
ForemanOT	Numeric	Scale	Input
GeneralForemanRT	Numeric	Scale	Input
GeneralForemanOT	Numeric	Scale	Input
LaborRT	Numeric	Scale	Input
LaborOT	Numeric	Scale	Input
LaborForemanRT	Numeric	Scale	Input
LaborForemanOT	Numeric	Scale	Input
LeadHandRT	Numeric	Scale	Input
LeadHandOT	Numeric	Scale	Input
OperatorRT	Numeric	Scale	Input
OperatorOT	Numeric	Scale	Input
RapStudentRT	Numeric	Scale	Input

SuperintendRT	Numeric	Scale	Input
SuperintendOT	Numeric	Scale	Input
SupervisorRT	Numeric	Scale	Input
SupervisorOT	Numeric	Scale	Input
Supervisor1RT	Numeric	Scale	Input
Supervisor1OT	Numeric	Scale	Input
Supervisor2RT	Numeric	Scale	Input
Supervisor2OT	Numeric	Scale	Input
Supervisor3RT	Numeric	Scale	Input
Supervisor3OT	Numeric	Scale	Input
SurveyorRT	Numeric	Scale	Input
SurveyorOT	Numeric	Scale	Input
SwamperRT	Numeric	Scale	Input
SwamperOT	Numeric	Scale	Input
SUVProjectManagerLocation	Numeric	Nominal	Input
SUVPMTouringHRS	Numeric	Scale	Input
SUVWorkerInspectionPercentage	Numeric	Scale	Input
SUVWorkerInteractionPercentage	Numeric	Scale	Input
SUVJHandSMeetingRepresentation	Numeric	Scale	Input
SUVTimeOnSafetyDuties	Numeric	Scale	Input
SUVMentoring	Numeric	Nominal	Input
SUVNumberOfSafetyInteractions	Numeric	Scale	Input
SUVHoursOfSafetyInteractions	Numeric	Scale	Input

SUVTypeOfContract	String	Nominal	Input
SUVScheduleAtProjectEnd	String	Nominal	Input
SUVSchedulePriorToStart	String	Nominal	Input
OLTI	Numeric	Scale	Output
ODaysLost	Numeric	Scale	Output
OMedicalAids	Numeric	Scale	Output
OFirstAids	Numeric	Scale	Output
OModifiedWork	Numeric	Scale	Output
OModifiedWorkDays	Numeric	Scale	Output
OAHazards	Numeric	Scale	Output
OBHazards	Numeric	Scale	Output
OCHazards	Numeric	Scale	Output

Table 5.1

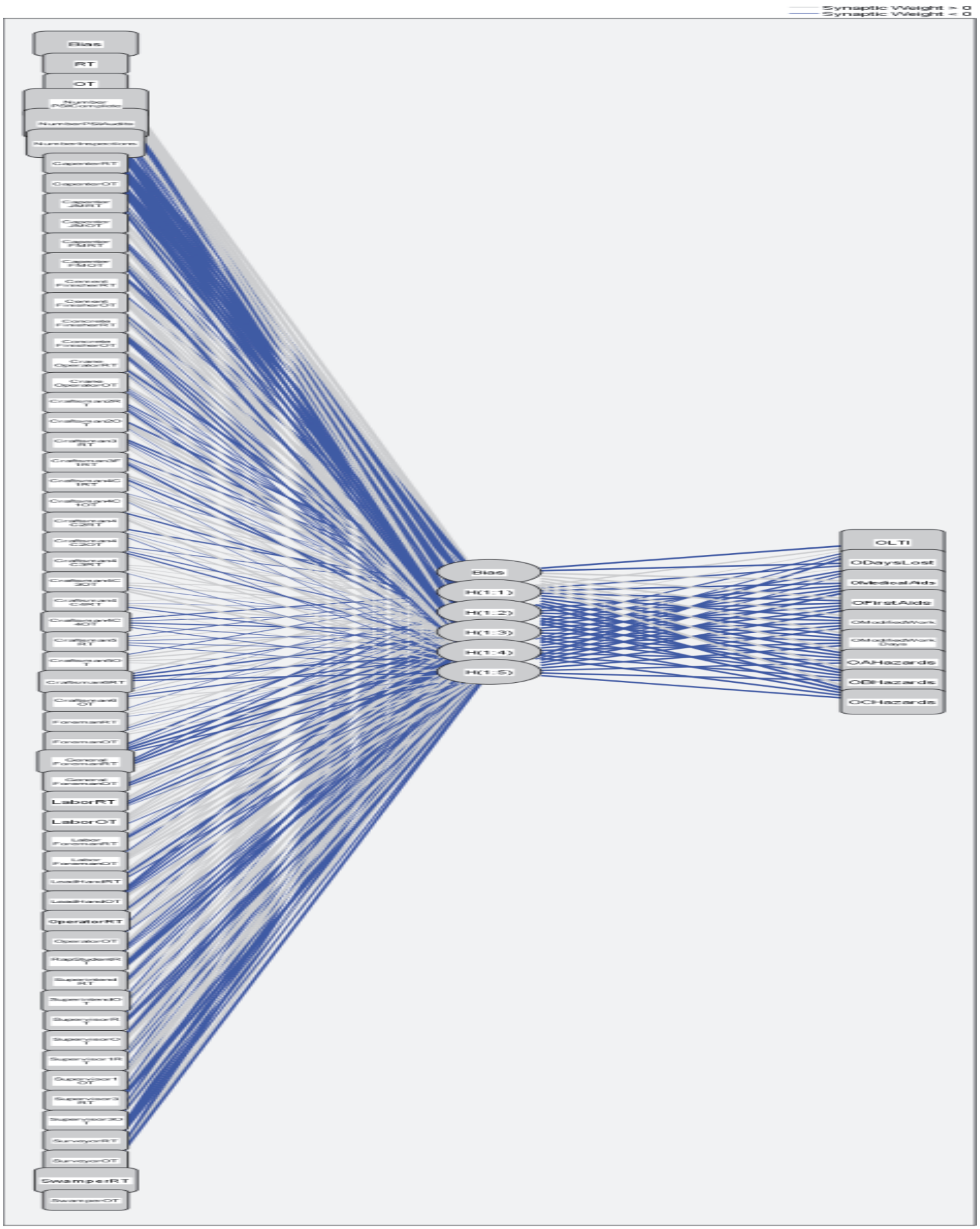

Synaptic Weight > 0
Synaptic Weight < 0
Bias
RT
OT
LaborRT
LaborOT
OperatorRT
SwamperRT
Bias
H(1:1)
H(1:2)
H(1:3)
H(1:4)
H(1:5)
OLTI
ODaysLost
OFirstAids
OAHazards
OBHazards
OCHazards

Figure 5.14

Configuration 1 produced some interesting results. Figure 4.15 is a chart of the normalized importance for inputs used in this configuration and Table 4.2 shows the values from this chart.

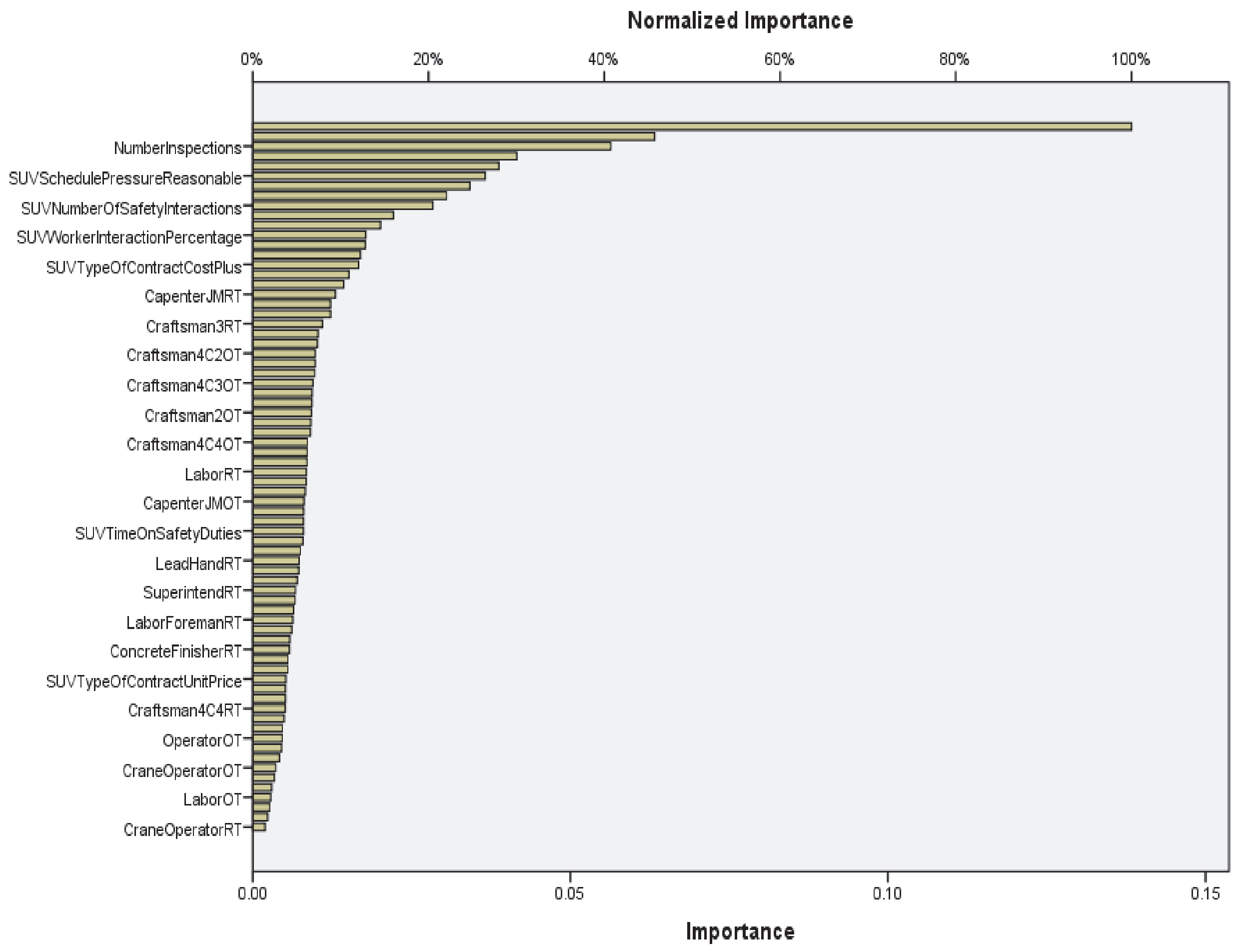


Figure 5.15

Independent Variable Importance		
	Importance	**Normalized Importance**
SUVProjectManagerLocation	.138	100.0%
Number SSHA Complete	.063	45.8%
NumberInspections	.056	40.7%
SUVMentoring	.042	30.0%
SUVTypeOfContractLumpSum	.039	28.0%
SUVSchedulePressureReasonable	.037	26.5%
Number SSHA Audits	.034	24.7%
SUVWorkerInspectionPercentage	.030	22.0%
SUVNumberOfSafetyInteractions	.028	20.5%
SUVScheduleOn	.022	16.0%
Craftsman6RT	.020	14.5%
SUVWorkerInteractionPercentage	.018	12.9%
Craftsman2RT	.018	12.8%
OT	.017	12.3%
SUVTypeOfContractCostPlus	.017	12.1%
CapenterRT	.015	10.9%
OperatorRT	.014	10.3%
CapenterJMRT	.013	9.4%
Supervisor3OT	.012	8.8%

GeneralForemanOT	.012	8.8%
Craftsman3RT	.011	7.9%
SUVScheduleBehind	.010	7.4%
Craftsman3OT	.010	7.4%
Craftsman4C2OT	.010	7.1%
SUVScheduleAhead	.010	7.1%
SUVTypeOfContractCMAtRisk	.010	7.0%
Craftsman4C3OT	.009	6.8%
Craftsman4C1RT	.009	6.7%
LaborForemanOT	.009	6.7%
Craftsman2OT	.009	6.7%
GeneralForemanRT	.009	6.6%
Craftsman5OT	.009	6.6%
Craftsman4C4OT	.009	6.2%
SUVJHandSMeetingRepresentation	.009	6.2%
CapenterFMRT	.009	6.2%
LaborRT	.008	6.1%
Craftsman4C1OT	.008	6.1%
SUVPMTouringHRS	.008	6.0%
CapenterJMOT	.008	5.8%
CementFinisherOT	.008	5.8%
CementFinisherRT	.008	5.8%
SUVTimeOnSafetyDuties	.008	5.8%

SuperintendOT	.008	5.7%
CapenterFMOT	.007	5.4%
LeadHandRT	.007	5.3%
RT	.007	5.2%
Craftsman5RT	.007	5.1%
SuperintendRT	.007	4.8%
Craftsman3F1RT	.007	4.8%
ConcreteFinisherOT	.006	4.6%
LaborForemanRT	.006	4.5%
ForemanOT	.006	4.4%
ForemanRT	.006	4.2%
ConcreteFinisherRT	.006	4.2%
Craftsman4C3RT	.006	4.0%
SUVHoursOfSafetyInteractions	.006	4.0%
SUVTypeOfContractUnitPrice	.005	3.8%
LeadHandOT	.005	3.7%
SurveyorRT	.005	3.7%
Craftsman4C4RT	.005	3.7%
CapenterOT	.005	3.6%
Craftsman4C2RT	.005	3.4%
OperatorOT	.005	3.3%
Supervisor1RT	.005	3.3%
SupervisorOT	.004	3.0%

CraneOperatorOT	.004	2.6%
Supervisor3RT	.003	2.4%
SurveyorOT	.003	2.1%
LaborOT	.003	2.0%
SupervisorRT	.003	1.9%
SUVSchedulePressureAggressive	.002	1.7%
CraneOperatorRT	.002	1.4%

Table 5.2

The results show that the network put a heavy influence on the location of the project manager (whether located on site or off site). The network placed the importance of this factor over twice that of the next highest factor. It was because of this discrepancy between the importance of factors that the other two configurations were created. The goal for the next two configurations was to reduce the number of factors to reduce the noise in the data and to see if the factors of highest importance would remain constant throughout the configurations.

Configuration 2

Configuration 2 had the goal of reducing the number of inputs. In order to achieve this goal without drastically changing the identity of the model, the inputs had to be reduced in a logical way. Trades that had multiple inputs used to represent them, because they had multiple skill levels being recorded, were combined into a single input. The trade groups that had their inputs combined were as follows: craftsmen (all skills levels combined into one factor), supervisors (all supervisor levels combined into a single supervisor factor), concrete and cement finishers were combined into one factor, carpenter and journeymen carpenter were combined into a single factor, and foreman and general foreman were also combined into a single factor. Table 4.3 lists the inputs and outputs used in version 2. For the weights of the configuration refer to Appendix C.

Field/Attribute	**Field Type**	**Measure**	**Role in the ANN**
ProjectNumber	Numeric	Scale	Input
RT	Numeric	Scale	Input
OT	Numeric	Scale	Input
Number SSHA Complete	Numeric	Scale	Input
Number SSHA Audits	Numeric	Scale	Input
NumberInspections	Numeric	Scale	Input
CapenterRT	Numeric	Scale	Input
CapenterOT	Numeric	Scale	Input
CapenterForemanRT	Numeric	Scale	Input
CapenterForemanOT	Numeric	Scale	Input
ConcreteAndCementFinisherRT	Numeric	Scale	Input
ConcreteAndCementFinisherOT	Numeric	Scale	Input
SafetyOfficerRT	Numeric	Scale	Input
SafetyOfficerOT	Numeric	Scale	Input
CraneOperatorRT	Numeric	Scale	Input
CraneOperatorOT	Numeric	Scale	Input

CraftsmanRT	Numeric	Scale	Input
CraftsmanOT	Numeric	Scale	Input
ForemanAndGeneralForemanRT	Numeric	Scale	Input
ForemanAndGeneralForemanOT	Numeric	Scale	Input
LaborRT	Numeric	Scale	Input
LaborOT	Numeric	Scale	Input
LaborForemanRT	Numeric	Scale	Input
LaborForemanOT	Numeric	Scale	Input
LeadHandRT	Numeric	Scale	Input
LeadHandOT	Numeric	Scale	Input
OperatorRT	Numeric	Scale	Input
OperatorOT	Numeric	Scale	Input
RapStudentRT	Numeric	Scale	Input
SuperintendRT	Numeric	Scale	Input
SuperintendOT	Numeric	Scale	Input
SupervisorRT	Numeric	Scale	Input
SupervisorOT	Numeric	Scale	Input
SurveyorRT	Numeric	Scale	Input
SurveyorOT	Numeric	Scale	Input
SUVProjectManagerLocation	Numeric	Nominal	Input
SUVPMTouringHRS	Numeric	Scale	Input
SUVWorkerInspectionPercentage	Numeric	Scale	Input
SUVWorkerInteractionPercentage	Numeric	Scale	Input

SUVJHandSMeetingRepresentation	Numeric	Scale	Input
SUVTimeOnSafetyDuties	Numeric	Scale	Input
SUVMentoring	Numeric	Nominal	Input
SUVNumberOfSafetyInteractions	Numeric	Scale	Input
SUVHoursOfSafetyInteractions	Numeric	Scale	Input
SUVTypeOfContract	String	Nominal	Input
SUVScheduleAtProjectEnd	String	Nominal	Input
SUVSchedulePriorToStart	String	Nominal	Input
OLTI	Numeric	Scale	Output
ODaysLost	Numeric	Scale	Output
OMedicalAids	Numeric	Scale	Output
OFirstAids	Numeric	Scale	Output
OModifiedWork	Numeric	Scale	Output
OModifiedWorkDays	Numeric	Scale	Output
OAHazards	Numeric	Scale	Output
OBHazards	Numeric	Scale	Output
OCHazards	Numeric	Scale	Output

Table 5.3

The results from configuration 2 show that the normalized importance was more evenly spread between factors. It also shows that the factors based on project manager behaviors have a higher importance than the hours worked from each respective trade. Figure 4.16 is a chart of the normalized importance for inputs used in this configuration and Table 4.4 is the values from this chart.

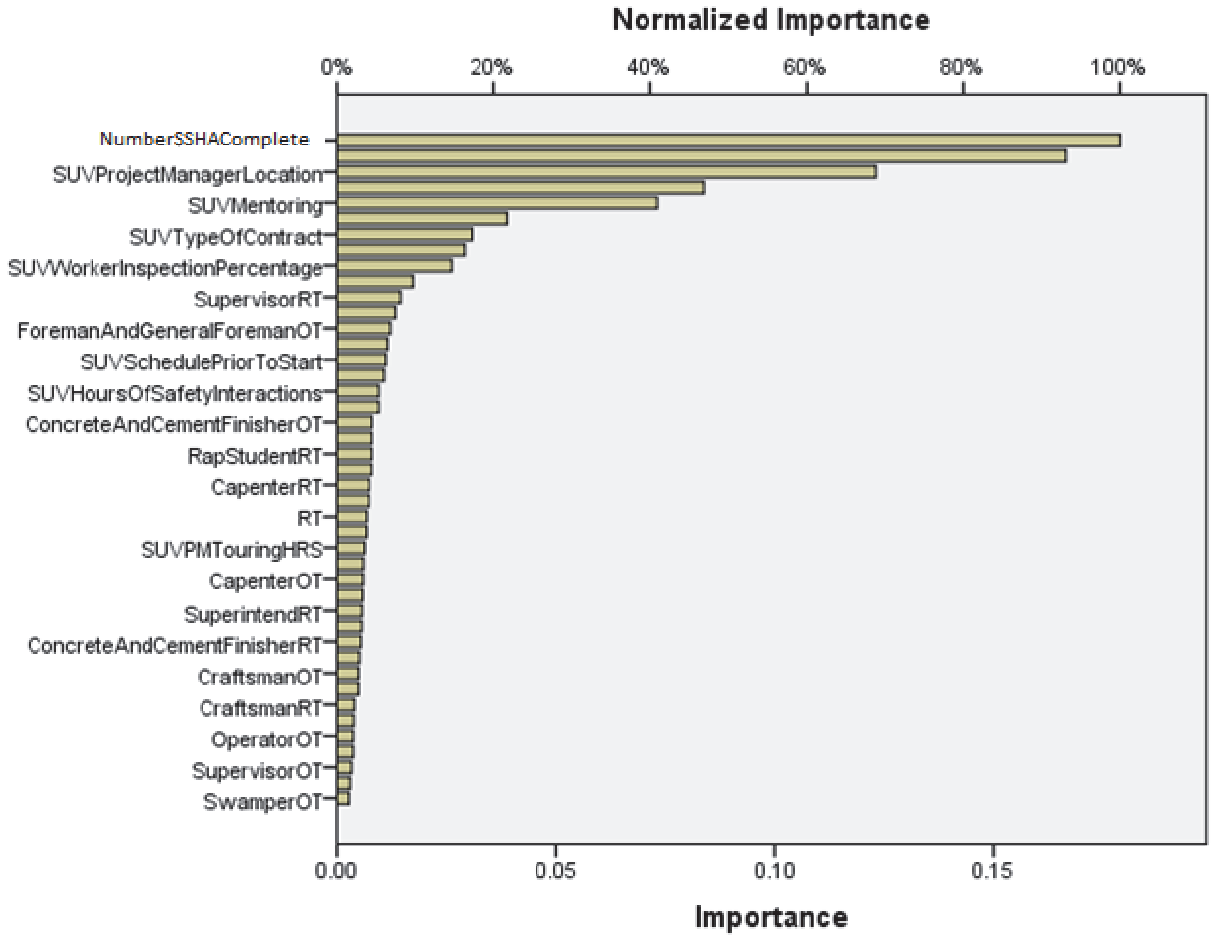


Figure 5.16

Independent Variable Importance			
#		Importance	Normalized Importance
1	Number SSHA Complete	.179	100.0%
2	NumberInspections	.166	93.1%
3	SUVProjectManagerLocation	.123	68.9%
4	Number SSHA Audits	.084	46.9%
5	SUVMentoring	.073	40.9%
6	LaborOT	.039	21.7%
7	SUVTypeOfContract	.031	17.2%
8	SUVNumberOfSafetyInteractions	.029	16.3%
9	SUVWorkerInspectionPercentage	.026	14.7%
10	SUVScheduleAtProjectEnd	.017	9.7%
11	SupervisorRT	.015	8.1%
12	LaborRT	.013	7.5%
13	ForemanAndGeneralForemanOT	.012	6.8%
14	SafetyOfficerRT	.012	6.5%

15	SUVSchedulePriorToStart	.011	6.3%
16	SUVJHandSMeetingRepresentation	.011	6.0%
17	SUVHoursOfSafetyInteractions	.010	5.4%
18	SUVWorkerInteractionPercentage	.010	5.4%
19	ConcreteAndCementFinisherOT	.008	4.5%
20	LeadHandRT	.008	4.5%
21	RapStudentRT	.008	4.5%
22	SUVTimeOnSafetyDuties	.008	4.4%
23	CapenterRT	.007	4.1%
24	ForemanAndGeneralForemanRT	.007	4.1%
25	RT	.007	3.8%
26	SurveyorRT	.007	3.7%
27	SUVPMTouringHRS	.006	3.5%
28	SafetyOfficerOT	.006	3.3%
29	CapenterOT	.006	3.3%
30	LeadHandOT	.006	3.3%

31	SuperintendRT	.006	3.1%
32	LaborForemanOT	.006	3.1%
33	ConcreteAndCementFinisherRT	.005	3.0%
34	LaborForemanRT	.005	2.8%
35	CraftsmanOT	.005	2.7%
36	SurveyorOT	.005	2.7%
37	CraftsmanRT	.004	2.2%
38	OT	.004	2.1%
39	OperatorOT	.004	2.1%
40	OperatorRT	.004	2.0%
41	SupervisorOT	.003	1.8%
42	SwamperRT	.003	1.7%
43	SwamperOT	.003	1.5%

Table 5.4

Based on these results from configuration 2, the focus for the third configuration would be too narrow on the factors produced from the survey results to see what impact they would have if there were less factors being represented by the manhours worked by each trade.

Configuration 3

In order to focus on the inputs from the survey response, the factor/inputs from the project data needed to be reduced. To achieve this, the factors representing the hours worked were combined into the following factors: trade regular hours, trade overtime hours, supervisor regular hours, and supervisor overtime hours. Table 4.5 shows the list of factors generated in configuration 3. For the weights of the configuration refer to Appendix C.

Field/Attribute	**Field Type**	**Measure**	**Role in ANN**
ProjectNumber	Numeric	Scale	Input
RT	Numeric	Scale	Input
OT	Numeric	Scale	Input
Number SSHA Complete	Numeric	Scale	Input
Number SSHA Audits	Numeric	Scale	Input
NumberInspections	Numeric	Scale	Input
TradeRT	Numeric	Scale	Input
TradeOT	Numeric	Scale	Input
SupervisorRT	Numeric	Scale	Input
SupervisorOT	Numeric	Scale	Input
SUVProjectManagerLocation	Numeric	Nominal	Input
SUVPMTouringHRS	Numeric	Scale	Input
SUVWorkerInspectionPercentage	Numeric	Scale	Input

SUVWorkerInteractionPercentage	Numeric	Scale	Input
SUVJHandSMeetingRepresentation	Numeric	Scale	Input
SUVTimeOnSafetyDuties	Numeric	Scale	Input
SUVMentoring	Numeric	Nominal	Input
SUVNumberOfSafetyInteractions	Numeric	Scale	Input
SUVHoursOfSafetyInteractions	Numeric	Scale	Input
SUVTypeOfContract	String	Nominal	Input
SUVScheduleAtProjectEnd	String	Nominal	Input
SUVSchedulePriorToStart	String	Nominal	Input
OLTI	Numeric	Scale	Output
ODaysLost	Numeric	Scale	Output
OMedicalAids	Numeric	Scale	Output
OFirstAids	Numeric	Scale	Output
OModifiedWork	Numeric	Scale	Output
OModifiedWorkDays	Numeric	Scale	Output
OAHazards	Numeric	Scale	Output
OBHazards	Numeric	Scale	Output
OCHazards	Numeric	Scale	Output

Table 5.5

The results from configuration three show that factors based on inspections had the highest impact on the safety perfromance of a construction site. The number of inspections, SSHA (site specific hazard assessment) completed, and the number that were audited were all shown to be of the highest importance. The next highest factors both pertain to the presence of the project manager. If the project manager was located on site and mentoring, then he/she would have a postive presence on the project. Figure 4.17 is a chart of the normalized importance for inputs used in this configuration and Table 4.6 their values.

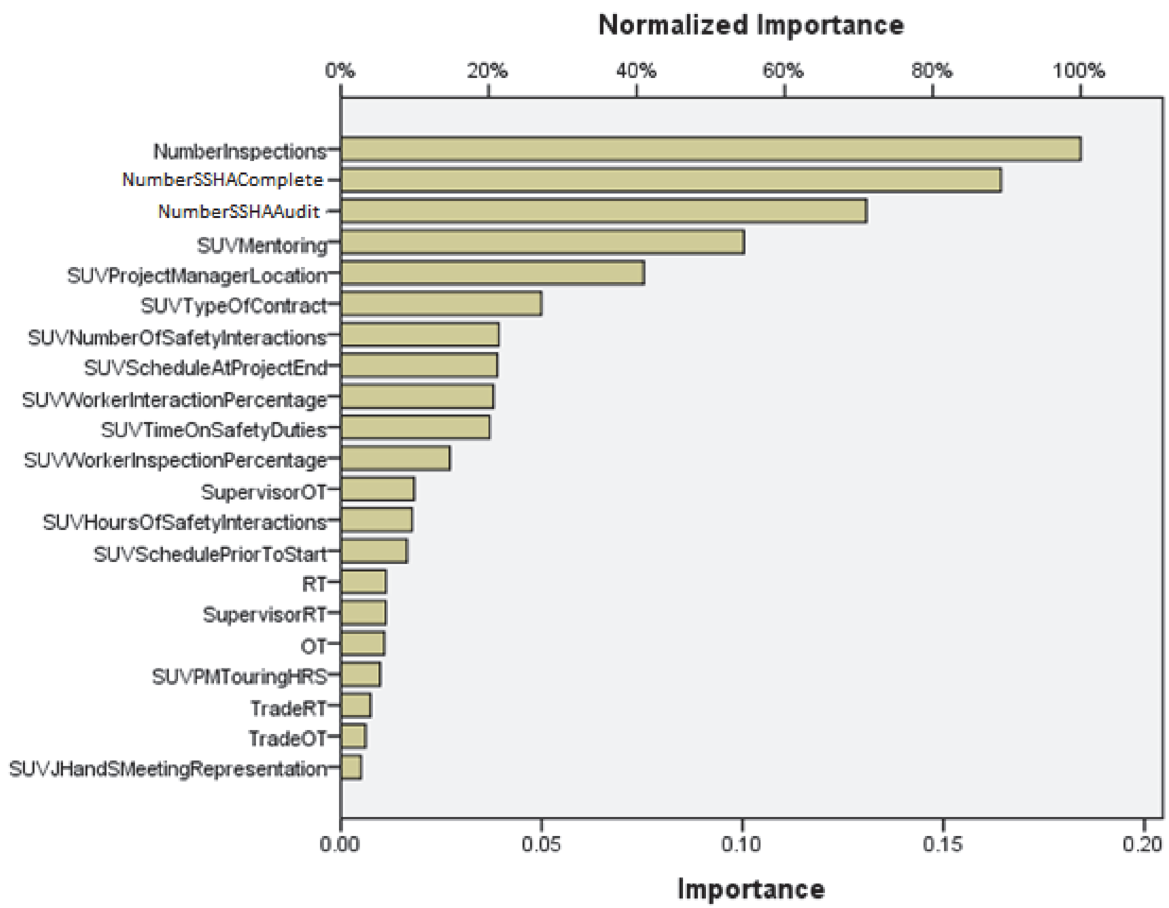


Figure 5.17

Independent Variable Importance			
Rank		**Importance**	**Normalized Importance**
1	NumberInspections	.184	100.0%
2	Number SSHA Complete	.164	89.2%
3	Number SSHA Audits	.131	71.0%
4	SUVMentoring	.100	54.5%
5	SUVProjectManagerLocation	.075	40.9%
6	SUVTypeOfContract	.050	27.1%
7	SUVNumberOfSafetyInteractions	.039	21.4%
8	SUVScheduleAtProjectEnd	.039	21.2%
9	SUVWorkerInteractionPercentage	.038	20.6%
10	SUVTimeOnSafetyDuties	.037	20.1%
11	SUVWorkerInspectionPercentage	.027	14.8%
12	SupervisorOT	.018	10.0%
13	SUVHoursOfSafetyInteractions	.018	9.6%

14	SUVSchedulePriorToStart	.016	9.0%
15	RT	.011	6.1%
16	SupervisorRT	.011	6.1%
17	OT	.011	5.9%
18	SUVPMTouringHRS	.010	5.3%
19	TradeRT	.007	4.0%
20	TradeOT	.006	3.4%
21	SUVJHandSMeetingRepresentation	.005	2.7%

Table 5.6

Error and Validation of Configurations

The ANN model configurations were validated in two ways. The first was through the self-validation that artificial neural networks do as part of the model training process. By splitting the data into training and testing sets, the network then uses the testing set to valid itself. It will configure the model using the training set and then calculate the error of predictions using the testing set. The error of all three configurations was compiled and can be found in Table 4.7.

Model Summary			Configuration 1	Configuration 2	Configuration 3
Training	Sum of Squares Error		4.628	1.132	2.379
	Average Overall Relative Error		1.000	.223	.472
	Relative Error for Scale Dependents	OLTI	1.001	1.087	1.004
		ODaysLost	1.001	1.041	1.042
		OMedicalAids	1.000	.031	.347
		OFirstAids	1.000	.048	.377
		OModifiedWork	1.001	.039	.676
		OModifiedWorkDays	.998	.044	.555
		OAHazards	1.001	.050	.281
		OBHazards	1.001	.017	.098
		OCHazards	1.002	.029	.168
	Stopping Rule Used		1 consecutive step(s) with no decrease in error	1 consecutive step(s) with no decrease in error	1 consecutive step(s) with no decrease in error
	Training Time		0:00:00.01	0:00:00.01	0:00:00.01
Testing	Sum of Squares Error		.481	.018	.107
	Average Overall Relative Error		1.057	1.443	4.158
	Relative Error for Scale Dependents	OLTI	.b	.b	.b
		ODaysLost	.b	.b	.b

		OMedicalAids	.b	.b	.b
		OFirstAids	1.115	1.128	257.711
		OModifiedWork	.b	.b	3.798
		OModifiedWorkDays	.b	.b	4.120
		OAHazards	.675	1.092	1.736
		OBHazards	1.029	1.317	2.837
		OCHazards	.836	1.603	2.675
a. Error computations are based on the testing sample.					
b. Cannot be computed. The dependent variable may be constant in the testing sample.					

Table 5.7

The error in configuration 1 was constant between training and testing. The error for days lost, medical aid, lost time incidents (LTI), modified work incidents, and modified work days could not be computed due to the small number found within the data set. Looking at the sum of squares error (SSE) for configuration 1, compared to the other two configurations, it was significantly higher. This was most like due to the increased number of inputs adding extra noise within the data set. Configuration 2 had the lowest SSE of all three configurations, in both training and testing. This validated the decision to combine factors that performed similar roles on a construction project. Configuration 2 did see a small increase in the relative errors of the model outputs, but this increase was quite small compared to the decrease in the SSE. The third configuration saw an increase when compared to the second configuration, particularly in the first aid output error. This suggests that the data set used in the model should not be simplified to the extent that was done for this configuration.

The model was also validated through the experience of industry professionals. The results from all three configurations were brought to industry members to determine if they were in-line with what they have seen in their years of experience. The industry professionals found that the results matched what they had seen in practice.

Discussion of Results

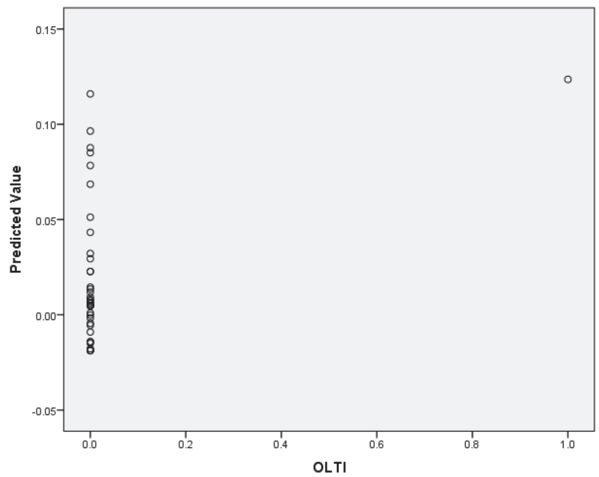
Configuration 2 was selected for further discussion because it produced the best results in terms of error. Figure 4.18 shows the tables for the predicted results from the neural network verses the observed data from the data sets. The outputs were grouped into two sections: outputs that performed well and those that performed poorly. Table 4.8 shows the mean, standard deviation, and the maximum and minimum values of the set. The reason why some outputs performed better than others was due to the noisiness of data. Some outputs had large spikes in the data which the network had a difficult time overcoming. The outputs that had consistency in the model were predicted well but those with high standard deviations were predicted poorly.

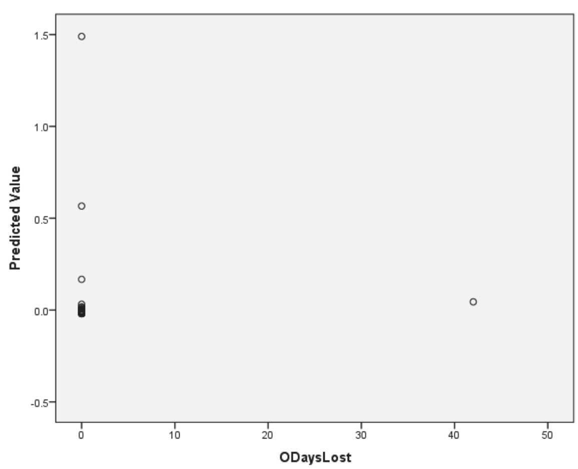
The outputs that were predicted well were the following:

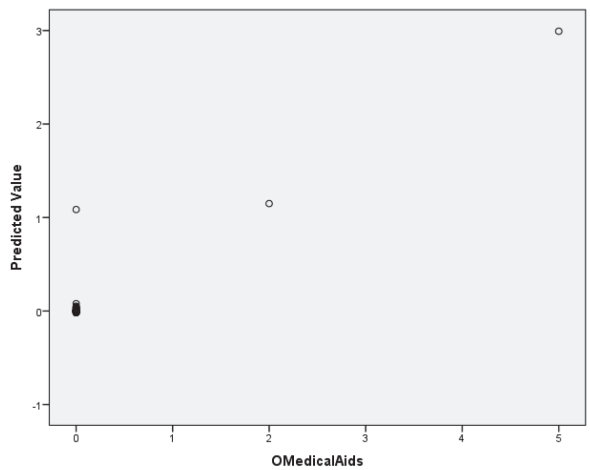
- Lost Time Incidents
- Days Lost
- Medical Aids

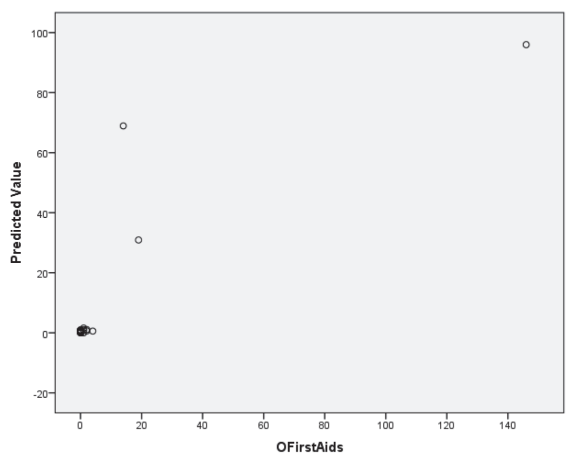
The outputs that were predicted poorly were the following:

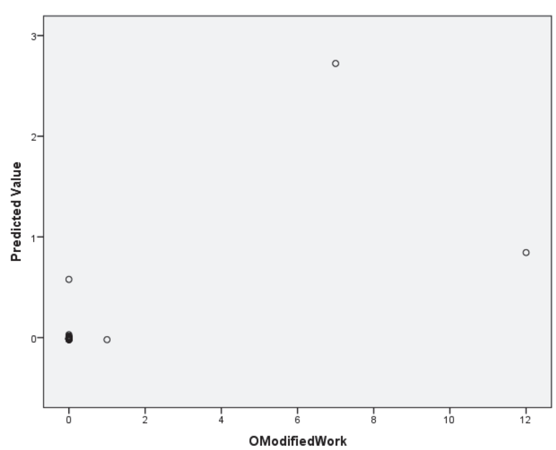
- First Aids
- Modified Work
- Modified Work Days
- A Hazards
- B Hazards
- C Hazards

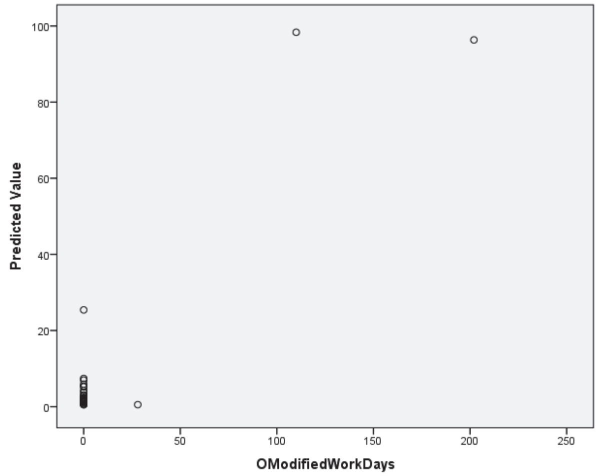


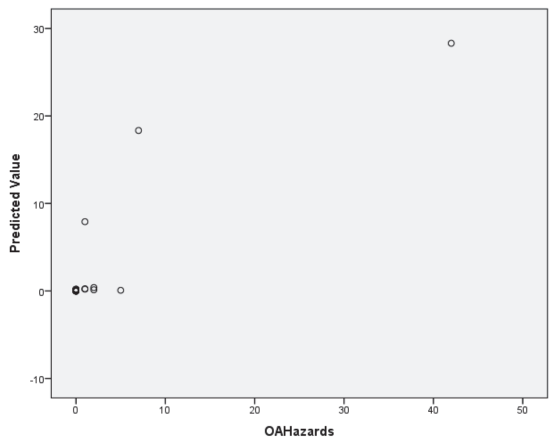


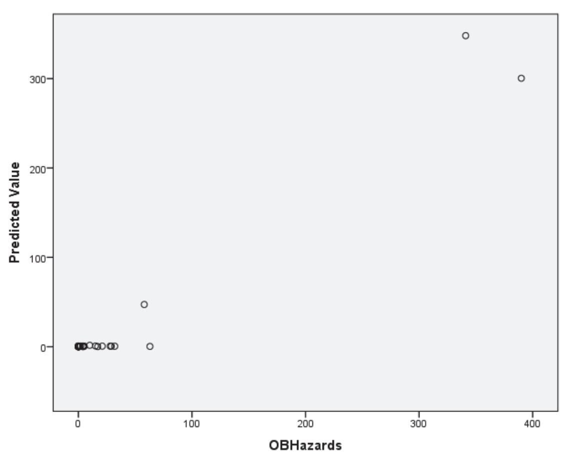

Predicted Value
OMedicalAids

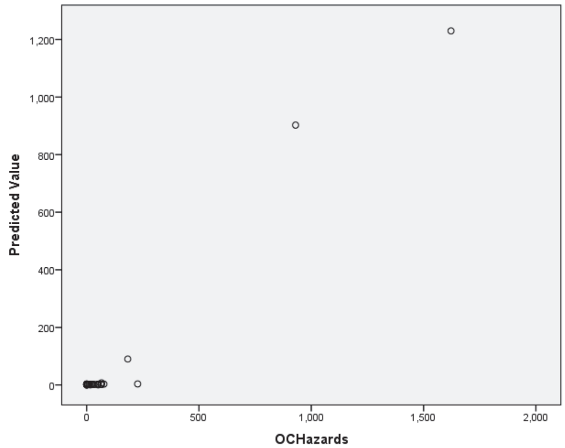

Predicted Value
OFirstAids


Predicted Value
OModifiedWork


Predicted Value
100
80
60
40
20
0
0
50
100
150
200
250
OModifiedWorkDays


Predicted Value
30
20
10
0
-10
0
10
20
30
40
50
OAHazards


Predicted Value
300
200
100
0
0
100
200
300
400
OBHazards



1,200
1,000
800
600
400
200
0
Predicted Value
0
500
1,000
1,500
2,000
OCHazards

Figure 5.18

Safety Outputs	O- LTI	O- DL	O - MA	O - FA	O - MW	O - MWD	O - A Haz	O-B Haz	O-C Haz
Mean	0.022	0.933	0.156	4.2444	0.467	7.7333	1.4	23.36	81.689
STD DEV (Sample)	0.149	6.261	0.796	21.893	2.052	34.066	6.333	76.17	274.5
Max	1	42	5	146	12	202	42	390	1622
Min	0	0	0	0	0	0	0	0	0

Table 5.8

Predictive Application

A predictive application could be developed using configuration 2 of the model. Configuration 2 would be selected for use in the application as it had the best overall error of all three configurations. The application would take the model framework from configuration 2. The user would have 5 sections of inputs that would be required to be filled out.

The first section that would require input from the user would be the project details section. In the section, the user would have to fill in the contract type (i.e. P3, lump sum, unit price, etc.), the aggressiveness of the planned schedule, and whether the project was most likely to be behind schedule, on schedule, or ahead of schedule.

The next section would be details pertaining to the project manager. The user would need to input whether the project manager would be located on or off site, if a mentoring program would be used on a site, the number of hours the project manager plans to spend touring the project site (per week), the percentage of tours taken by the project manager that he/she will take the time to stop and talk with the workers, their planned H&S meeting representation, the project manager's planned hours per week spent on safety related duties, the planned number of interactions the project manager will have with the project safety personnel and the number of hours that will equate to.

The third section would be the estimated manhours of the project. The user would need to input the expected regular and overtime hours worked by each trade (the same ones used in configuration two of the model), and the total regular and OT hours of the project.

The final section would be about the safety practices. The user would need to input the expected number of SSHAs that will be completed and audited, as well as the number of formal inspections that will be completed.

Based on the inputs provided by the user, the application would then predict the number of each type of incident that would be expected to occur as well as the number of hazards that will be identified. Figures 4.19 and 4.20 show a sample of the input and output tabs of the proposed predictive application.

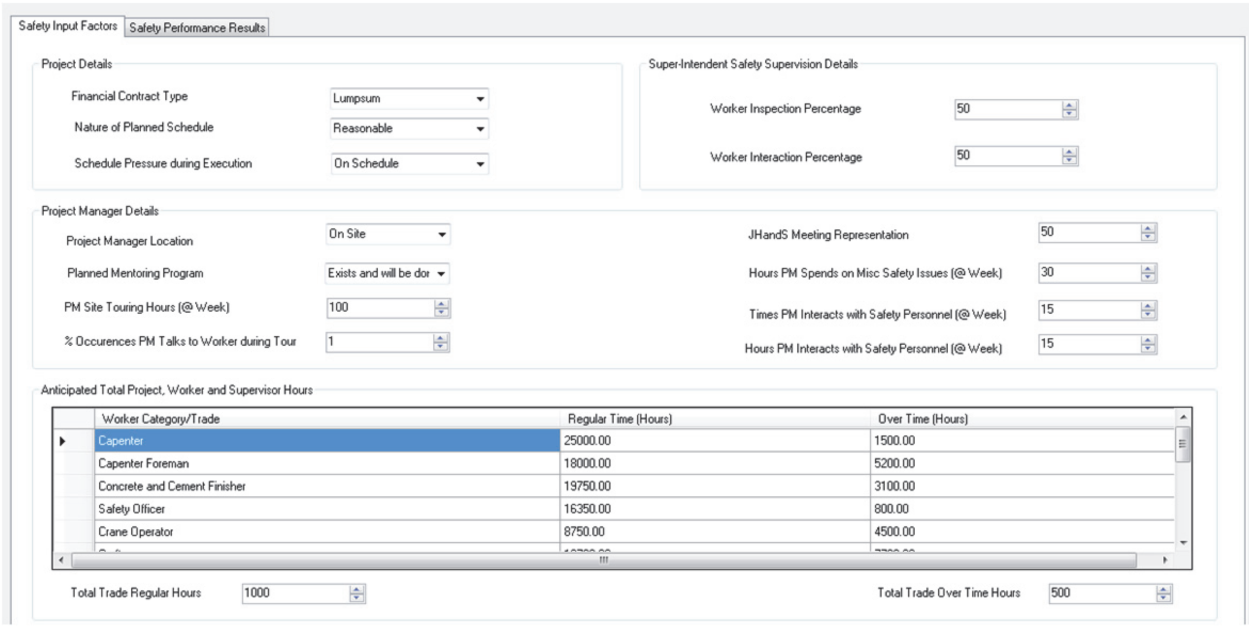


Figure 5.19

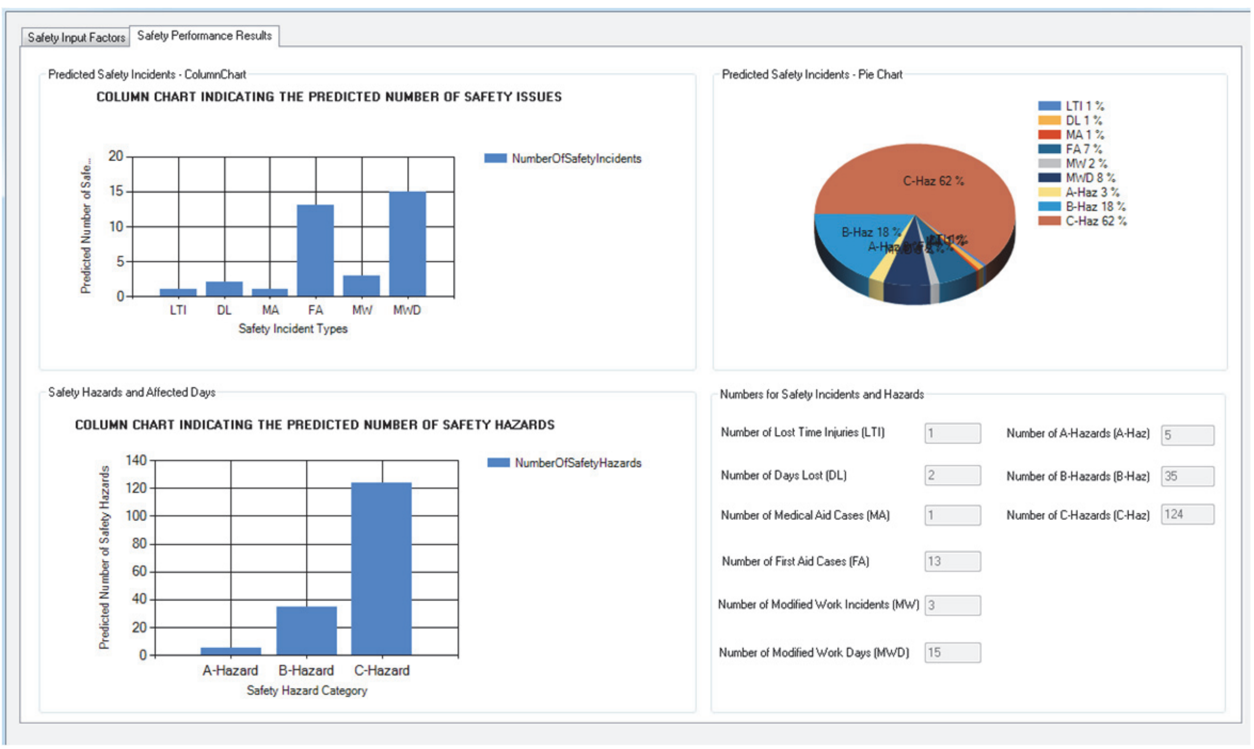


Figure 5.20

The value of this application would not be the predicted number of incidents, since the goal of every project is to have zero safety incidents, the actual number of predicted incidents is not as valuable as seeing the impact of changing the inputs on the predicted results. For example, the application could be used to see what value would be gained in terms of safety performance by auditing more SSHAs or having 3 more hours spent by the project manager on safety each week. The application could assist the user in deciding how they should allocate resources in terms of safety.

Due to time constraints, this application was not actually be developed, but the concepts would still be relevant.

6. Conclusions and Recommendations

Conclusions

The goal of this study was to answer the question, what makes a project safe? In order to answer this question, a set of factors coming from both historical project data and surveys of project managers were created. To assist with the analysis of this data, a feed-forward back propagating neural network was developed.

This study focused on both the collection of data to develop factors that could be used to represent a construction project and its safety performance, as well the analysis of the factors using a neural network. Through research and interviews with industry members, a set of factors that had available and collectable data was created. A portion of this data was collected from historical project information such as safety reports and time card information. In order to collect the other portion of data, a survey was developed and administered to project managers. This collected data was organized into three different configurations that would be experimented upon using an artificial neural network (ANN). All three configurations used the same network topology, which consisted of a sigmoid transfer function, a single hidden layer with 5 nodes. Based on the results from all three configurations, it became clear that certain factors had a greater impact on safety than others. Table 5.1 summarizes the ten factors with the highest importance from each configuration. Throughout all three configurations, the factors related to inspections were within the top 4 factors in order of importance (formal inspections, SSHA completed, and audits completed on SSHAs). Based on these results, it can be concluded that a crucial component to having a safe project is to constantly be inspecting and re-evaluating the project site for safety hazards. Throughout the life of the project, the physical layout will go through many changes. As the project goes through the changes, so do the potential hazards. The results of this study would suggest that completing inspections frequently was an effective tool at making constructions projects safer. Mentoring, project manager location, the number of interactions project managers had with safety personnel and workers were found within the 10 top factors of highest importance for all three configurations. This suggests that another conclusion that could be made was that the presence of the project manager played a key role in making a project safe. This could be contributed to the fact that if the project manager is located on the site, mentoring and sharing his experiences, and being available to listen to the concerns of both the safety professionals and workers on the project, then he/she will have a strong sense of what is happening on the project.

Configuration 1	**Configuration 2**	**Configuration 3**

1. Number of Formal Inspections Completed	1.Mentoring program on site	1. Number of formal inspections completed
2. Project Manager located on/off site	2.Number of SSHA audited	2. Number of SSHA completed
3. Number of SSHA completed	3. Number of SSHA completed	3.Number of SSHA audited
4.Number of SSHA audited	4. Number of formal inspections completed	4. Mentoring program on site
5.Craftsman level 6 regular hours	5. Foreman regular time hours	5. Project Manager located on/off site
6. Type of contract	6. Foreman overtime hours	6. Type of contract
7. Mentoring program on site	7. Type of contract	7. Number of project manager interactions with safety personnel
8. General Foreman overtime hours	8. Number of project manager interactions with safety personnel	8. Whether the project finished behind, on time, or ahead of

		schedule
9. Number of project manager interactions with Safety Personnel	9. Percentage that a Project Manager would stop and interact with workers when on site	9. Time project manager spent on safety related duties
10. Percentage of inspections that had a worker brought along	10. Whether the project finished behind, on time, or ahead of schedule	10. Percentage that a Project Manager would stop and interact with workers when on site

Table 6.1

They would be able to correct any negative trends in worker behavior as soon as they appeared, or put measures in place to control any hazards as they appeared. If the project manager is located off site or isn't in touch with the front line workers (both the safety professionals and craft workers), they would not be in a position to make the required changes is the same time period as compared to if they had a stronger presence on site. The type of contract and the schedule of the project were also factors that had high importance within the three configurations. A conclusion was made that some contract types allowed for increased flexibility to make changes for safety, while others did not provided that flexibility. For example, a unit price contract includes rates for everything associated with the construction of that project, if additional measures are required to mitigate potential safety hazards that were not present in the original estimate of the job, there is a rate that can be charged to put those measures in place. For a lump sum project there is a fixed price for the work. If additional measures are needed after the contract award, it requires more effort and time to get the proper funding for those measures, or the contractor takes a loss for those costs. For both scenarios, it would add an additional level of resistance to putting those measures in. A conclusion that could be made for the schedule of the project was that when projects fall behind schedule, an added level of pressure is placed on the workers to finish the job quicker to try and meet the schedule. This pressure placed on workers may cause them to lose focus or rush, resulting in an increased potential for injuries.

Recommendations

This study was completed using data gathered from a single construction company, operating in the building sector. Limitations were faced due to the lack of data collected by the contracting company. The following are recommendations for future collection of data:

1. Collect data on the workers of the project. Collecting this information would show trends about the workforce to see what impact the quality of the workforce has on the safety performance.
    a. Their age
    b. Their years of experience
    c. Past incident/injury history
    d. Their perception of schedule pressure
    e. Their opinion of the safety culture on site

2. Collect additional quality information about the project. This information could identify the impact that the quality of engineering and the contractor had on the safety performance of the project.
    a. Number of requests for information (RFI) submitted on the project
    b. Number of changes introduced by the owner of the project
    c. Number of quality issues
3. Collect information pertaining to the physical aspects of the project. Impacts related to the physical aspect of the project could be identified through the collection of this data.
    a. Area of project (broken down to area of open space and space used by project)
    b. A measure for the congestion of the site
    c. Weather conditions throughout the construction of project
4. Collect information from projects of similar size. This would decrease the noise in the data and increase predictability of the data when using artificial neural networks.
5. Collect information regarding spending on safety. This information could show impacts of training and spending on safety, and also be used to further investigate the impacts that the contract type have on safety.
    a. Amount of money spent on training
    b. Amount spent on PPE for workers
    c. Amount spent/number of safety personal on the project

In order to make recommendations for taking the principles of this study into the industrial sector of construction, which was one of the largest sectors in of construction in Alberta, interviews with project management and safety professional were conducted. The industrial construction sector was broken down into three main sections and interviews conducted with members from each section. The sections were as follows: shutdown/maintenance work, project site work, and fabrication facilities. They were asked what they felt were unique challenges in terms of safety for their industry. The following recommendations were made based on their input.

Shop facility

The factors that the industry members felt unique to a shop facility were:

- The facilities typically have low turnover because of the highly desired atmosphere
    - Familiar with physical area
    - Have time to be trained and coached
    - Can have a well-established safety culture
    - Participate in safety training design
    - Safety re-training after certain period of time
- The environment is controlled
    - Weather isn't a factor
    - Crowding can become an issue
    - No at height activities
- Single trade operation in shop
    - Communication between trades isn't an issue
    - Low variety in project tasks, possibly easier to mitigate risks
- Management support
    - Safety incentive programs (free lunch every other week based on crew engagement and involvement in safety)
    - Regular auditing of safety programs

- Cannot be looked at on a per project basis as many projects are ongoing and a worker may work on multiple projects within the same day.

Site work

Factors unique to site work identified by industry members are:

- Remoteness
    - Sites are often located far away from medical facilities
- Shift work
    - An increased level of communication needed between changing shifts
    - Shift rotation (some shifts can be very long and fatigue can play a factor)
    - Hours in a shift (some vary from 8-12 hours)
- Desirability of positions
    - Often newer safety professionals found on site. May not have a lot of experience and require further training. Management doesn't account for this when gauging number of safety professionals needed on a site; may lead to insufficient supervision.

Shut down/maintenance construction

The unique factors associated with shut down work were identified as the following:

- Nature of working on a plant that was once live
    - Increased congestion
    - Dangerous chemicals in the area
- Nature of shutdown work

- High number of workers needed for short duration of work (often need to get workers from all areas)
- Bring in new permitting officers (often are familiar with plant)
- Long shifts with few rest days (leads to worker fatigue and increased chances of incidents)
- Short duration of projects (all the same safety requirements of a large project with less time to do it, often means management are tied up with paper work)
- Difficult to develop a positive safety culture

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8. Appendix A

VIEW000072

1.1 Study Identification

*All questions marked by a red asterisk * are required fields. However, because the mandatory fields have been kept to a minimum, answering only the required fields may not be sufficient for the REB to review your application.*

Please answer all relevant questions that will reasonably help to describe your study or proposed research.

1.0 * **Short Study Title** *(restricted to 250 characters)*:
An Investigation into Factors That Make Projects Safe

2.0 * **Complete Study Title** *(can be exactly the same as short title)*:

An investigation into factors that make projects safe

3.0 * **Select the appropriate Research Ethics Board (***Detailed descriptions are available by clicking the HELP link in the upper right hand corner of your screen***):**
REB 1

4.0 * **Is the proposed research:**
Funded (Grant, subgrant, contract, internal funds, donation or some other source of funding)

5.0

* **Name of Principal Investigator** *(at the University of Alberta, Covenant Health, or Alberta Health Services)*:
Lance Cooper

6.0

Investigator's Supervisor *(required for applications from undergraduate students, graduate students, post-doctoral fellows and medical residents to Boards 1, 2, 3. HREB does not accept applications from student PIs)*

Simon Abourizk

7.0 * **Type of research/study:**
Graduate Student - Thesis, Dissertation, Capping Project

8.0 **Study Coordinators or Research Assistants:**
People listed here can edit this application and will receive all HERO notifications for the study:

Name	Employer
Amy Carter	EN Civil & Env Engineering

9.0 **Co-Investigators:** People listed here can edit this application but do not receive HERO notifications unless they are added to the study email list: Name Employer

There are no items to display

10.0 **Study Team** *(Co-investigators, supervising team, other study team members):* People listed here cannot edit this application and do not

receive HERO notifications:

Last Name	First Name	Organization	Role/Area of Responsibility	Phone	Email
Carter	Amy	University of Alberta	Techincal Writer		ajcarter@ualberta.ca
Al-Hussein	Maria		System Analyst		maria.al-hussein@ualberta.ca

1.3 Study Funding Information

1.0

* **Type of Funding:**

Grant (external)

If OTHER, provide details:
This project is under Dr.Simaan AbouRizk, NSREC Industrial Research Chair in Construction Engineering and Management

2.0

* **Indicate which office administers your award.** *(It is the PI's responsibility to provide ethics approval notification to any office other than the ones listed below)*
University of Alberta - Research Services Office (RSO)

If OTHER, provide details:

3.0 * **Funding Source**

3.1 Select all sources of funding from the list below:
There are no items to display

3.2 If not available in the list above, write the Sponsor/Agency name(s) in full (you may add multiple funding sources):
View Canadian Institute of Steel Construction (CISC) View PME Inc (Partner Company)
View JV Driver Projects Inc (Partner Company)
View Graham Group (Partner Company)
View Standard General Inc. (Partner Company)
View Finning - Canada (Partner Company)
View North American Construction Group (Partner Company)
View KBR Canada Ltd. (Partner Company) View Ledcor Group (Ledcor Group)
View The City of Edmonton - Infrastructure Services (Partner Company) View PCL Constructors Inc. (Partner Company)
View Insituform Technologies (Partner Company)
View NSERC - Natural Science and Engineering Research Council
View Waiward Steel Fabricators Ltd. (Partner Company)
View Flint Energy Services Ltd. (Partner Company) View E Construction Ltd. (Partner Company)
View The City of Edmonton - Transportation Services (Partner Company)
View Alberco Construction Ltd.

4.0

* **Indicate if this research sponsored or monitored by any of the following:**

Not applicable

If applicable, indicate whether or not the FDA Investigational New Drug number or FDA Investigational Device Exception is required:

The researcher is responsible for ensuring that the study complies with the applicable US regulations. The REB must also meet particular review criteria and this application will likely receive full board review, regardless of level risk.

1.4 RSO Managed Funding

1.0 **If your funds are managed by Research Services Office (RSO), select the Project ID and title from the list below to facilitate release of your study funds.** *(Not available yet)*

2.0 * **To connect your ethics application with your funding: provide all identifying information about the study funding – multiple rows allowed. For Project ID, enter a Funding ID provided by RSO/PeopleSoft Project ID** *(for example, RES0005638, G018903401, C19900137, etc).* **Enter the corresponding title for each Project ID.**

	Project ID	Project Title	Speed Code	Other Information
View	RES0008414	NSERC IRCPJ 19558	1052C	
View	RES0008038	Multi/16 IRC 195558	1053C	

1.5 Conflict of Interest

1.0

* **Are any of the investigators or their immediate family receiving any personal remuneration (including investigator payments and recruitment incentives but excluding trainee remuneration or graduate student stipends) from the funding of this study that is not accounted for in the study budget?**

Yes **No**

If YES, explain:

2.0 * **Do any of investigators or their immediate family have any proprietary interests in the product under study or the outcome of the research including patents, trademarks, copyrights, and licensing agreements?**

Yes **No**

3.0 **Is there any compensation for this study that is affected by the study outcome?**

Yes **No**

4.0 **Do any of the investigators or their immediate family have equity interest in the sponsoring company? (This does not include Mutual Funds)**

Yes **No**

5.0 **Do any of the investigators or their immediate family receive payments of other sorts, from this sponsor (i.e. grants, compensation in the form of equipment or supplies, retainers for ongoing consultation and honoraria)?**

Yes **No**

6.0 **Are any of the investigators or their immediate family, members of the sponsor's Board of Directors, Scientific Advisory Panel or comparable body?**

Yes **No**

7.0 **Do you have any other relationship, financial or non-financial, that, if not disclosed, could be construed as a conflict of interest?**

Yes **No**

If YES, explain:

Important
If you answered YES to any of the questions above, you may be contacted by the REB for more information or asked to submit a Conflict of Interest Declaration.

1.6 Research Locations and Other Approval

1.0 * **List the locations of the proposed research, including recruitment activities. Provide name of institution or organization, town, or province as applicable**
Data from PCL Constructors Inc. databases from projects that were located throughout Alberta will be used in this study. Surveys will be administered at the PCL Constructors Inc. office (Edmonton, Alberta). The data will be analyzed and the results will be compiled at the University of Alberta, in the NREF building (Edmonton, Alberta).

2.0 * **Indicate if the study will use or access facilities, programmes, resources, staff, students, specimens, patients or their records, at any of the sites affiliated with the following** *(select all that apply):*
Not applicable

List all facilities or institutions as applicable:

3.0

Multi-Institution Review

* **3.1 Has this study already received approval from another REB?**
Yes **No**

Name
There are no items to display

4.0

Does this study involve pandemic or similar emergency health research?
Yes **No**

If YES, are you the lead investigator for this pandemic study?
Yes No

5.0 **If this application is closely linked to research previously approved by one of the University of Alberta REBs or has already received ethics approval from an external ethics review board*(s)*, provide the HERO study number, REB name or other identifying information. Attach any external REB application and approval letter in Section 7.1.11 – Other Documents.**

2.1 Study Objectives and Design

1.0 Date that you expect to start working with human participants:
22/07/2013

2.0 Date that you expect to finish working with human participants, in other words, you will no longer be in contact with the research participants, including data verification and reporting back to the group or community:
05/08/2013

3.0 * Provide a lay summary of your proposed research suitable for the general public *(restricted to 300 words)*. **If the PI is not affiliated with the University of Alberta, Alberta Health Services or Covenant Health, please include institutional affiliation.**

The purpose of the study is to compare construction projects focused in the building construction sector from one construction company to determine which factors make a project safer than others. The study consists of looking at second hand safety, time card, and budgeting data for those projects and surveying the project managers of those projects to gather behaviour based data.

4.0 * **Provide a description of your research proposal including study objectives, background, scope, methods, procedures, etc)** *(restricted to 1000 words)*. **Footnotes and references are not required and best not included here. Research methods questions in Section 5 will prompt additional questions and information.**

1.0 Background

Safety is a major concern, not only for construction, but in every industry. The construction industry in particular has been labelled as a notoriously unsafe industry to work in. Because of this, there has been a strong push to improve safety in construction. Factors have been identified to evaluate the overall safety performance of construction companies, but they have never been used to look at which ones specifically make projects safer than others.

2.0 Objectives

(i) Gather second hand data from a single construction company, in the areas of safety, payroll, and safety budgets.

(ii) Analyze gathered data through use of neural network simulation.

(iii) Determine which factors make projects safer than others.

3.0 Scope

This study will be done on the information provided second hand from PCL Constructors Inc. in the building construction sector.

4.0 Methods

4.1 Experimental Design

Factors affecting safety will be identified through review of literature on construction safety. Data will be received from construction projects which can be used to formulate the identified factors for each project. A survey of Project Managers and Superintendents will be done to obtain information for factors that cannot be found in data (behavioural factors). The formulated factors will be compared between projects through use of a neural network and the factors that have the highest affect on the number of safety incidents will be identified.

4.2 Data Collection

The data used has been previously collected and stored in PCL Constructors Inc. database. Paper surveys of project managers and superintendents will be collected in addition to the data previously collected. These paper surveys will then be transferred to electronic versions.

4.3 Data Analysis

Data will be analyzed and results gathered through the use of a neural networks.

5.0 **Describe procedures, treatment, or activities that are above or in addition to standard practices in this study area** *(eg. extra medical or health-related procedures, curriculum enhancements, extra follow-up, etc)*:

6.0 **If the proposed research is above minimal risk and is not funded via a competitive peer review grant or industry-sponsored clinical trial, the REB will require evidence of scientific review. Provide information about the review process and its results if appropriate.**

7.0 **For clinical research only, describe any sub-studies associated with this application.**

3.1 Risk Assessment

1.0 * **Provide your assessment of the risks that may be associated with this research:**
Minimal Risk - research in which the probability and magnitude of possible harms implied by participation is no greater than those encountered by participants in those aspects of their everyday life that relate to the research (TCPS2)

2.0 * **Select all that might apply:**

Description of Potential Physical Risks and Discomforts

No	Participants might feel physical fatigue, e.g. sleep deprivation
No	Participants might feel physical stress, e.g. cardiovascular stress tests
No	Participants might sustain injury, infection, and intervention side-effects or complications
No	The physical risks will be greater than those encountered by the participants in everyday life

Potential Psychological, Emotional, Social and Other Risks and Discomforts

No	Participants might feel psychologically or emotionally stressed, demeaned, embarrassed, worried, anxious, scared or distressed, e.g. description of painful or traumatic events
No	Participants might feel psychological or mental fatigue, e.g intense concentration required
Possibly	Participants might experience cultural or social risk, e.g. loss of privacy or status or damage to reputation
No	Participants might be exposed to economic or legal risk, for instance non-anonymized workplace surveys
No	The risks will be greater than those encountered by the participants in everyday life

3.0 * **Provide details of the risks and discomforts associated with the research, for instance, health cognitive or emotional factors, socio-economic status or physiological or health conditions:**

The only risk involved with this study is if location of the stored information is compromised and somehow leaked. However, this is very unlikely because the data is stored on password protect computers.

There are no health or emotional risks involved in this study.

4.0 * **Describe how you will manage and minimize risks and discomforts, as well as mitigate harm:**
A confidentiality agreement has been signed as one step to minimize the risk; in addition, all information is stored under password protection. Any information used regarding individuals will have their personal information removed as well.

5.0 * **If your study has the potential to identify individuals that are upset, distressed, or disturbed, or individuals warranting medical attention, describe the arrangements made to try to assist these individuals. Explain if no arrangements have been made:**
This study won't identify individuals so these incidents have no potential to occur.

3.2 Benefits Analysis

1.0 * **Describe any potential benefits of the proposed research to the participants. If there are no benefits, state this explicitly:**
The benefits the participants gain is the knowledge of which factors have a impact on safety. This information could be used to improve their overall performance.

2.0 * **Describe the scientific and/or scholarly benefits of the proposed research:**
Gaining the knowledge of which factors make a construction project safer than others and to what extent are the scientific/scholarly benefits gained through this research.

3.0 **Benefits/Risks Analysis: Describe the relationship of benefits to risk of participation in the research:**

4.1 Participant Information

1.0 * **Who are you studying? Describe the population that will be included in this study.**
The population of the study is PCL Constructors Inc. The study is looking at construction projects managed by PCL Constructors Inc. The study will also involve a survey of Project Managers/Superintendents from PCL Constructors Inc.

2.0 * **Describe the inclusion criteria for participants (e.g. age range, health status, gender, etc.). Justify the inclusion criteria (e.g. safety, uniformity, research methodology, statistical requirement, etc)**

The inclusion criteria is projects (randomly selected) from PCL Constructors Inc.'s database (inlcudes data for projects that they were the general contractor on). Project Managers/Superintendent from the randomly selected projects will also be surveyed.

3.0 Describe and justify the exclusion criteria for participants:

4.0

* **Will you be interacting with human subjects, will there be direct contact with human participants, for this study?**

Yes No

Note: No means no direct contact with participants, chart reviews, secondary data, interaction, etc.

If NO, is this project a chart review or is a chart review part of this research project?

Yes No

5.0

Participants

How many participants do you hope to recruit *(including controls, if applicable)*

50

Of these how many are controls, if applicable *(Possible answer: Half, Random, Unknown, or an estimate in numbers, etc).*

0

If this is a multi-site study, for instance a clinical trial, how many participants *(including controls, if applicable)* **are expected to be enrolled by all investigators at all sites in the entire study?**

6.0 Justification for sample size:

7.0 Does the research specifically target aboriginal groups or communities?

Yes **No**

4.3 Recruit Potential Participants

1.0

Recruitment

* **1.1 Describe how you will identify potential participants (please be specific as to how you will find potentially eligible participants i.e. will you be screening AHS paper or electronic records, will you be looking at e-clinician, will you be asking staff from a particular area to let you know when a patient fits criteria, will you be sitting in the emergency department waiting room, etc.)**
Construction projects were selected at random from a PCL database, each of those projects had a Project Manager and Superintendents that worked on those projects. Those Project Managers and Superintendents will be approached for participation.

1.2 Once you have identified a list of potentially eligible participants, indicate how the potential participants' names will be passed on to the researchers AND how will the potential participants be approached about the research.

1.3 How will people obtain details about the research in order to make a decision about participating? Select all that apply:

Researchers will contact potential participants

1.4 If appropriate, provide the locations where recruitment will occur *(e.g schools, shopping malls, clinics, etc.)*

2.0

Pre-Existing Relationships

2.1 Will potential participants be recruited through pre-existing relationships with researchers *(e.g. Will an instructor recruit students from his classes, or a physician recruit patients from her practice? Other examples may be employees, acquaintances, own children or family members, etc)***?**

Yes **No**

2.2 If YES, identify the relationship between the researchers and participants that could compromise the freedom to decline *(e.g. professor-student)***. How will you ensure that there is no undue pressure on the potential participants to agree to the study?**

3.0 **Outline any other means by which participants could be identified, should additional participants be needed** *(e.g. response to advertising such as flyers, posters, ads in newspapers, websites, email, listservs; pre-existing records or existing registries; physician or community organization referrals; longitudinal study, etc)*

There are no other means to identify additional participants. If additional participants are needed, more projects will be randomly selected from PCL's database.

4.0 **Will your study involve any of the following** *(select all that apply)***?**

None of the above

4.5 Informed Consent Determination

1.0

* **Describe who will provide informed consent for this study (select all that apply). Additional information on the informed consent process is available at: http://www.pre.ethics.gc.ca/eng/policy-politique/initiatives/tcps2-eptc2/chapter3-chapitre3/#toc03-intro**

All participants have capacity to give free and informed consent

Provide justification for requesting a Waiver of Consent (Minimal risk only, additional guidance available at: http://www.pre.ethics.gc.ca/eng/policy-politique/initiatives/tcps2-eptc2/chapter3-chapitre3/#toc03-1b

2.0

How is participant consent to be indicated and documented? Select all that apply:

Implied by overt action (i.e. completion of questionnaire)

Except for "Signed consent form" use only, explain how the study information will be communicated and participant consent will be documented. Provide details for EACH of the option selected above:
A letter of information and consent has been prepared which indicates the study information and that how participants give consent through completion of the survey.

3.0

Authorized Representative, Third Party Consent, Assent

3.1 Explain why participants lack capacity to give informed consent *(e.g. age, mental or physical condition, etc.).*

3.2 Will participants who lack capacity to give full informed consent be asked to give assent?
● Yes ● No

Provide details. IF applicable, attach a copy of assent form(s) in the Documentation section.

3.3 In cases where participants (re)gain capacity to give informed consent during the study, how will they be asked to provide consent on their own behalf?

4.0 **What assistance will be provided to participants, or those consenting on their behalf, who have special needs?** *(E.g. non-English speakers, visually impaired, etc)***:**

5.0 * **If at any time a participant wishes to withdraw, end, or modify their participation in the research or certain aspects of the research, describe how their participation would be ended or changed.**
If PCL Constructors Inc. wishes that any particular project not be used, they would simply have to tell me the project number and that project and any data related to that project would be removed from the study. If the Project Manager from a particular site does not wish to participate, that project information will not be used.

6.0

Describe the circumstances and limitations of data withdrawal from the study, including the last point at which it can be done:
Participants will be allowed to withdraw completed surveys from the study freely, up to three weeks after they have been submitted. After that point they will not be able to withdraw. Data collected from those participants that withdrew will be removed from the study and destroyed.

7.0 **Will this study involve any group(s) where non-participants are present? For example, classroom research might involve groups which include participants and non-participants.**

Yes **No**

5.1 Research Methods and Procedures

Some research methods prompt specific ethic issues. The methods listed below have additional questions associated with them in this application. If your research does not involve any of the methods listed below, ensure that your proposed research is adequately described in Section 2.0: Study Objectives and Design or attach documents in Section 7.0 if necessary.

1.0 * **This study will involve the following** *(select all that apply)*
The list only includes categories that trigger additional page(s) for an online application. For any other methods or procedures, please indicate and describe in your research proposal in the Study Summary, or provide in an attachment:
Surveys and Questionnaires (including internet surveys)

2.0 * **Is this study a Clinical trial? (Any investigation involving participants that evaluates the effects of one or more health-related interventions on health outcomes?**
Yes **No**

3.0 **If you are using any tests in this study diagnostically, indicate the member(s) of the study team who will administer the measures/instruments:**

Test Name	Test Administrator	Organization	Administrator's Qualification

There are no items to display

4.0 **If any test results could be interpreted diagnostically, how will these be reported back to the participants?**

5.7 Interviews, Focus Groups, Surveys and Questionnaires

1.0
Are any of the questions potentially of a sensitive nature?
Yes **No**

If YES, provide details:

2.0
If any data were released, could it reasonably place participants at risk of criminal or civil law suits?
Yes **No**

If YES, provide the justification for including such information in the study:

3.0 **Will you be using audio/video recording equipment and/or other capture of sound or images for the study?**

Yes **No**

If YES, provide details:

6.1 Data Collection

1.0 * **Will the researcher or study team be able to identify any of the participants at any stage of the study?**

Yes No

2.0 **Will participants be recruited or their data be collected from Alberta Health Services or Covenant Health or data custodian as defined in the Alberta Health Information Act?**

Yes **No**

Important: Research involving health information must be reviewed by the Health Research Ethics Board.

3.0 **Primary/raw data collected will be** *(check all that apply)***:**

All personal identifying information removed (anonymized)

4.0 **If this study involves secondary use of data, list all original sources:**

The source of the data is PCL Constructors Inc. The original data is project related data stored in their database.

5.0 **In research where total anonymity and confidentiality is sought but cannot be guaranteed** *(eg. where participants talk in a group)* **how will confidentiality be achieved?**

6.2 Data Identifiers

1.0 * **Personal Identifiers:** will you be collecting - at any time during the study, including recruitment - any of the following *(check all that apply)***:**

Surname and First Name
Employee ID Number

If OTHER, please describe:

2.0 **Will you be collecting - at any time of the study, including recruitment of participants - any of the following** *(check all that apply)***:**

There are no items to display

If OTHER, please describe:

3.0 * **If you are collecting any of the above, provide a comprehensive rationale to explain why it is necessary to collect this information:**
The surname and first name will be collected from the Project Managers and Superintendents to be approached for a survey regarding behavior based factors of each project. Their surname and first name will not being included in the study itself, but rather for use in data collection.

The employee ID number will be used to calculate the number of hours worked by each employed based on their training classification (i.e. Apprentice year 1, Apprentice year 2, Journeyman, etc). The total hours worked by each classification will be used for the study, but not the actual amount worked by the employee individually.

4.0 **If identifying information will be removed at some point, when and how will this be done?**
The surname and first name of the Project Managers and Superintendents will be removed after the completion of all the surveys. The identifying information will be kept in a separate data file and that file will be removed by not being included with the study's data files.

5.0 * **Specify what <u>identifiable</u> information will be RETAINED once data collection is complete, and explain why retention is necessary. Include the retention of master lists that link participant identifiers with de-identified data:**
No identifiable data will be retained once data collection is complete.

6.0 **If applicable, describe your plans to link the data in this study with data associated with other studies (e.g within a data repository) or with data belongong to another organization:**
This is not applicable.

6.3 Data Confidentiality and Privacy

1.0 * **How will confidentiality of the data be maintained? Describe how the identity of participants will be protected both during and after research.**
Confidentiality of the data will be maintained by having only the principle investigator looking at data that contains personal information. The principle investigator has signed a confidentiality agreement and will be responsible to keep the data secure by keeping the information password protected. The identities of the participants will be protected by being stored on a password protected computer, which can only be accessed by the principle investigator. Their identities will be deleted from the file after completion of the study.

2.0 **How will the principal investigator ensure that all study personnel are aware of their responsibilities concerning participants' privacy and the confidentiality of their information?**
Information containing personal information will only be viewed by the PI. The other study personnel will not have any direct contact with information

containing personal information. The other study personnel will be made aware that personal information was used to collect some parts of the data for the study and if they have questions regarding those parts to contact the PI about those parts.

3.0

External Data Access

* **3.1 Will identifiable data be transferred or made available to persons or agencies outside the research team?**

Yes **No**

3.2 If YES, describe in detail what identifiable information will be released, to whom, why they need access, and under what conditions? What safeguards will be used to protect the identity of subjects and the privacy of their data.

3.3 Provide details if identifiable data will be leaving the institution, province, or country *(eg. member of research team is located in another institution or country, etc.)*

6.4 Data Storage, Retention, and Disposal

1.0 * **Describe how research data will be stored, e.g. digital files, hard copies, audio recordings, other. Specify the physical location and how it will be secured to protect confidentiality and privacy.** *(For example, study documents must be kept in a locked filing cabinet and computer files are encrypted, etc. Write N/A if not applicable to your research)*

Electronic Format:
Electronic responses received will be downloaded and saved on a file server hosted in the Construction Research Group at the University of Alberta. Access to this file will be secured (password protected) and restricted to Maria Al-Hussein. The file on this server will be created and secured by Maria. Email threads with study responses will be deleted soon after downloading the responses.

Paper Format:
During the data collection and analysis phase of the study, responses/data will be addressed to Lance Cooper and subsequently locked up in a file cabinet within Maria's University office (in Natural Resources and Engineering Facility - NREF Building, room 5-050) then will remain under the custody of Maria Al-Hussein for the minimum mandatory 5 year period. After this period, these paper documents will be destroyed in a manner described in 3.0.

2.0 * **University policy requires that you keep your data for a minimum of 5 years following completion of the study but there is no limit on data retention. Specify any plans for future use of the data. If the data will become part of a data repository or if this study involves the creation of a research database or registry for future research use, please provide details.** *(Write N/A if not applicable to your research)*

Results from this study will be kept for at least the minimum stipulated period of 5 years. It is hoped that the results from this study can be used to assist further studies about company performance. If this is the case, a database will be created that stores such information and will be hosted at the University of Alberta (a neutral place) on a secure server in the Construction Engineering Research Group.

3.0

If you plan to destroy your data, describe when and how this will be done? Indicate your plans for the destruction of the identifiers at the earliest opportunity consistent with the conduct of the research and/or clinical needs:

Paper Format of Data Responses: The paper responses will be shredded at a designated shredding area for confidential materials within the Civil Engineering Department. This will be done after 5 years because this information will no longer be needed.

Electronic Data: This will be retained beyond the 5 years on a fire wall protected file server.

7.1 Documentation

Add documents in this section according to the headers. Use Item 11.0 "Other Documents" for any material not specifically mentioned below.

Sample templates are available in the REMO Home Page in the **Forms and Templates**, or by clicking HERE.

1.0 Recruitment Materials:

Document Name	Version	Date	Description
There are no items to display			

2.0 Letter of Initial Contact:

Document Name	Version	Date	Description
Disregard | History	0.03	17/07/2013 16:51	

3.0

Informed Consent / Information Document(s):

3.1 What is the reading level of the Informed Consent Form(s):

3.2 Informed Consent Form(s)/Information Document(s):

Document Name	Version	Date	Description
Information and Consent Letter | History	0.01	17/07/2013 16:50	

4.0 Assent Forms:

Document Name	Version	Date	Description
There are no items to display			

5.0 Questionnaires, Cover Letters, Surveys, Tests, Interview Scripts, etc.:

Document Name	Version	Date	Description
Safety Survey | History	0.01	04/07/2013 13:28	

6.0 Protocol:

Document Name	Version	Date	Description
There are no items to display			

7.0 Investigator Brochures/Product Monographs *(Clinical Applications only)*:

Document Name	Version	Date	Description
There are no items to display			

8.0 Health Canada No Objection Letter *(NOL)*:

Document Name	Version	Date	Description
There are no items to display			

9.0 Confidentiality Agreement:

Document Name	Version	Date	Description
Confidentiality Agreement for Lance Cooper | History	0.01	03/07/2013 13:48	

10.0 Conflict of Interest:

Document Name	Version	Date	Description
There are no items to display			

11.0 Other Documents:

For example, Study Budget, Course Outline, or other documents not mentioned above

Document Name	Version	Date	Description
There are no items to display			

Final Page

You have completed your ethics application! Please select "Exit" to go to your study workspace.

This action will NOT SUBMIT the application for review.

Only the Study Investigator can submit an application to the REB by selecting the "SUBMIT STUDY" button in My Activities for this Study ID: Pro00034261.

You may track the ongoing status of this application via the study workspace.

Please contact the REB Administrator with any questions or concerns.

Notification of Approval

Date:	July 26, 2013
Study ID:	Pro00034261
Principal Investigator:	Lance Cooper
Study Supervisor:	Simon Abourizk
Study Title:	An investigation into factors that make projects safe
Approval Expiry Date:	July 25, 2014

Approved Consent Form:	Approval Date	Approved Document
	7/26/2013	Information and Consent Letter

Sponsor/Funding Agency:

Ledcor Group (Ledcor Group)
PCL Constructors Inc. (Partner Company)
Canadian Institute of Steel Construction (CISC)
Insituform Technologies (Partner Company)
PME Inc (Partner Company)
Flint Energy Services Ltd. (Partner Company)
Finning - Canada (Partner Company)
Standard General Inc. (Partner Company)
Waiward Steel Fabricators Ltd. (Partner Company)
KBR Canada Ltd. (Partner Company)
Alberco Construction Ltd.
North American Construction Group (Partner Company)
E Construction Ltd. (Partner Company)
NSERC - Natural Science and Engineering Research Council
Graham Group (Partner Company)
The City of Edmonton - Infrastructure Services (Partner Company)
The City of Edmonton - Transportation Services (Partner Company)
JV Driver Projects Inc (Partner Company)

Thank you for submitting the above study to the Research Ethics Board 1. Your application has been reviewed and approved on behalf of the committee.

A renewal report must be submitted next year prior to the expiry of this approval if your study still requires ethics approval. If you do not renew on or before the renewal expiry date, you will have to re-submit an ethics application.

Approval by the Research Ethics Board does not encompass authorization to access the staff, students, facilities or resources of local institutions for the purposes of the research.

Sincerely,

Dr. William Dunn
Chair, Research Ethics Board 1

Note: This correspondence includes an electronic signature (validation and approval via an online system).

Research Study Information and Consent — Construction Safety Survey **07/17/13**

Dear ___,

You are invited to participate in a research study conducted by a representative of Dr. Simaan AbouRizk's Construction Engineering and Management Department at the University of Alberta, Lance Cooper, MSc student.

Your participation in this study is entirely voluntary. You should read the information below and ask questions about anything you do not understand, before deciding whether or not to participate.

Study Title: An Investigation into Factors That Make Projects Safe

Research Investigator:
Lance Cooper
MSc Student
NSERC Industrial Research Chair in Construction Engineering and Management
Department of Civil and Environmental Engineering
School of Mining and Petroleum Engineering
5-080 Markin/CNRL Natural Resources Engineering Facility (9105-116 Street)
University of Alberta
Edmonton, Alberta, Canada, T6G 2W2
Cell Phone: 780-707-3768
Email: lecooper@ualberta.ca

Supervisor:
S. M. AbouRizk, PhD, PEng
Professor of Civil Engineering and NSERC IRC in Construction Engineering, Canada Research Chair in Operation Simulation Department of Civil and Environmental Engineering
5-080 Natural Resources Engineering Facility (9105-116 Street)
University of Alberta
Edmonton, Alberta, Canada, T6G 2W2
Phone: 780-492-8096
Fax: 780-492-0249
Email: abourizk@ualberta.ca

Background:
You are invited to participate in this study because you were part of the management team on construction projects that were randomly chosen for use in my research study. Your information was passed on to me by PCL Constructors Inc. The results of this study will be used in support of my thesis.

Purpose of the Study:
The goal of the study is to improve construction company competitiveness by quantifying the impact that certain factors have on the safety performance of a construction site. This survey has been designed to obtain information about factors that cannot be obtained from the project data (behavioural factors). This study is funded by NSERC Industrial Research Chair in Construction Engineering and Management.

Study Procedures:
We are conducting a survey (roughly 30-60 minutes to complete) to determine information about factors affecting safety that cannot be obtained through construction data. Therefore, we request your participation in this research study by providing us with accurate information about the projects you worked on. Completing the survey indicates your agreement to participate in the research.

Lance Cooper will administer and receive your completed questionnaire, then analyze the responses. Please note that identifiers for participants (Project Managers' and Superintendents' names) will be retained during the data collection phase of the study for purposes of follow-up on questionnaire responses. After data collection, all identifiers will be destroyed and responses aggregated and analyzed independent of participant identities.

Anticipated Benefits Resulting From This Study:
The results of this study can be made available upon request. The study will help to increase understanding of the impact that the selected factors have on the safety performance of construction projects. There may not be any direct benefits to the respondents.

Risk:
The only foreseeable risk involved in the study is that should our storage server be comprised at any point your personal information (name and surname), with linked survey responses, could be released.

Voluntary Participation:
You are under no obligation to participate in this study; participation is completely voluntary. Submitted surveys can be withdrawn by participants that opt to, within three weeks from the date of receipt of the questionnaire and related documents. Withdrawal after this period will not be possible. Data for participants that withdraw will be disregarded and safely destroyed.

Confidentiality:
Any information that is obtained in connection with this study and that can be identified with your company will remain confidential. Confidentiality will be maintained by storing all electronic materials on a file server hosted in the Construction Research Group at the University of Alberta. Access to this file will be secured and restricted to Lance Cooper, and data/results will be restricted to the study team (Maria Al-Hussein (System Analyst), Amy Carter (Technical Writer), and Lance Cooper (Principle Investigator). Paper documents will be stored in a locked file cabinet during collection, then translated into electronic format and stored on the secured file server, and the paper copies shredded at a designated shredding area for confidential materials within the Civil Engineering Department.

We will not use your name in any of the information we get from this study or in any of the research reports. Information that can identify you individually, or direct survey responses will not be released to anyone outside the study. However, we may use results from this study for a thesis, for professional reports, and/or for academic conferences and publications.

Contact Information:
If you have any questions concerning this study, please contact **Lance Cooper, MSc Student**:
NSERC Industrial Research Chair in Construction Engineering and Management
Department of Civil and Environmental Engineering
School of Mining and Petroleum Engineering
3-133 Markin/CNRL Natural Resources Engineering Facility
University of Alberta, Edmonton, Alberta, Canada, T6G 2W2
Cell Phone: 780-707-3768, Email: lecooper@ualberta.ca

The plan for this study has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780) 492-2615. This office has no affiliation with the study investigators.

Thank you in advance for your participation.

Regards,

Lance Cooper
MSc Student
NSERC Industrial Research Chair in Construction Engineering and Management
Department of Civil and Envirornnental Engineering School of
Mining and Petroleum Engineering University of Alberta

9. Appendix B

	Total MHs	OT MHs	O- Number SSHA Com	O - Number SSHA Audits	O- Number Insp	Carpenter MHs	Carpenter OT
Mean	18748	1304	1035	59	46	10723	691
STD DEV{Sample)	48996	3138	3445	209	127	24838	1633
Max	271132	15784	21116	1311	722	112440	9301
Min	9	1	0	0	0	0	0

	CARPENTER JOURNEYMAN MHs	CARPENTER JOURNEYMAN OT	CARPENTER FOREMAN MHs	CARPENTER FOREMANOT	CEMENT FINISHER MHs	CEMENT FINISHEROT	CONCRETE FINISHER MHs
Mean	598	16	355	34	232	17	267
STD DEV{Sample)	3653	107	1356	125	1478	107	1118
Max	24436	718	8744	797	9917	721	7134
Min	0	0	0	0	0	0	0

	CONCRETE FINISHEROT	CONSTRUCTIO N SAFETY OFFICERMHs	CONSTRUCTIO N SAFETY OFFICEROT	CRANE OPERATOR MHs	CRANE OPERATOROT	CRAmM AN IMHs	CRAFTSM ANIOT	CRAFTSMAN II MHs	CRAFTSMAN II OT
Mean	21	17	1	355	50	0	0	50	2
STD DEV{Sample)	91	114	7	2379	336	0	0	171	6
Max	589	767	48	15956	2253	0	0	973	33
Min	0	0	0	0	0	0	0	-17	0

	CRAFTSMAN III MHs	CRAmMAN III OT	CRAmMAN III (F 1) MHs	CRAmMA N III (F 1) OT	CRAFTSMAN IV (C 1) MHs	CRAmMAN IV(C 1) OT	CRAmMAN IV(C2) MHs
Mean	5	1	0	0	28	1	30
STD DEV(Sample)	25	6	2	0	95	2	137
Max	161	42	16	0	518	13	873
Min	0	0	0	0	0	0	0

	CRAFTSMAN IV(C2) OT	CRAFTSMAN IV(C3) MHs	CRAFTSMAN IV (C3) OT	CRAFTSMAN IV(C4) MHs	CRAFTSMAN IV(C4) OT	CRAFTSMANV MHs	CRAFTSMANV OT	CRAFTSMAN VI (1) MHs
Mean	2	13	1	6	0	33	2	3
STD DEV(Sample)	10	50	7	31	1	134	7	18
Max	71	250	50	204	8	833	35	115
Min	0	0	0	0	0	0	0	0

	CRAFTSMAN VI (1) OT	FOREMAN MHs	FOREMANOT	GENERAL FOREMAN MHs	GENERAL FOREMANOT	LABOURMHs	LABOUROT	LABOUR FOREMAN MHs
Mean	0	27	2	465	48	4635	290	296
STD DEV(Sample)	0	183	17	1716	161	15587	831	1184
Max	1	1228	111	10955	779	97479	4566	7130
Min	0	0	0	0	0	0	0	0

	LABOUR FOREMANOT	LEADHAND MHs	LEADHANDOT	OPERATOR MHs	OPERATOROT	RAP STUDENT MHs	Superintendent MHs	Superintendent OT
Mean	32	18	2	110	7	10	161	19
STD DEV{Sample)	132	122	11	296	23	65	376	66
Max	768	819	77	1495	121	436	1802	391
Min	0	0	0	0	0	0	0	0

	SUPERVISOR MHS	SUPERVISOR OT	SUPERVISOR I MHS	SUPERVISOR I OT	SUPERVIS OR II MHs	SUPERVIS OR II OT	SUPERVISOR III MHs	SUPERVISOR III OT	SURVEYOR MHs
Mean	172	51	1	0	0	0	50	9	86
STD DEV{Sample)	635	168	6	0	0	0	186	44	515
Max	3719	824	35	2	0	0	799	287	3458
Min	0	0	0	0	0	0	0	0	0

	SURVEVOROT	SWAMPERMHs	SWAMPEROT	0-LTI	0-DL	0-MA	0-FA	0-MW
Mean	6	0	0	0	1	0	4	0
STD DEV{Sample)	27	0	0	0	6	1	22	2
Max	174	0	0	1	42	5	146	12
Min	0	0	0	0	0	0	0	0

	0-MWD	0-AHaz	0-B Haz	0-CHaz
Mean	8	1	23	82
STD DEV{Sample)	34	6	76	275
Max	202	42	390	1622
Min	0	0	0	0

10.Appendix C

Parameter Estimates

Predictor		Predicted														
		Hidden Layer 1					Output Layer									
		H(1:1)	H(1:2)	H(1:3)	H(1:4)	H(1:5)	OLTI	ODaysLost	OMedicalAids	OFirstAids	OModifiedWork	OModifiedWorkDays	OAHazards	OBHazards	OCHazards
Input Layer	(Bias)	1.013	1.222	-.131	.338	.299									
	[SUVProjectManagerLocation=-1]	.231	1.678	1.280	1.986	.931									
	[SUVProjectManagerLocation=1]	.253	-.744	-1.038	-1.504	-.641									
	[SUVMentoring=-1]	.336	-.714	.214	.019	.456									
	[SUVMentoring=0]	.261	-.122	-.603	-.126	-.216									
	[SUVMentoring=1]	.797	1.897	1.161	.976	1.557									
	[SUVTypeOfContractCMAtRisk=-1]	.870	.270	.247	.747	.612									
	[SUVTypeOfContractCMAtRisk=1]	.732	.220	.082	-.015	.228									
	[SUVTypeOfContractLumpSum=-1]	.544	1.117	-.725	-.822	.907									
	[SUVTypeOfContractLumpSum=1]	.289	-.600	1.247	.568	-.374									
	[SUVTypeOfContractCostPlus=-1]	.120	.447	.296	.803	.284									
	[SUVTypeOfContractCostPlus=1]	.160	.330	-.842	.280	.537									
	[SUVTypeOfContractUnitPrice=-1]	.500	.410	.169	.264	.605									
	[SUVTypeOfContractUnitPrice=1]	.608	.167	-.012	.233	-.079									
	[SUVScheduleOn=-1]	.241	1.498	.811	-.001	1.393									
	[SUVScheduleOn=1]	-.084	-.226	-.173	-.696	-.159									
	[SUVScheduleAhead=-1]	.931	.241	-.127	-.067	.641									
	[SUVScheduleAhead=1]	-.009	.548	.191	.537	.660									
	[SUVScheduleBehind=-1]	.832	-.090	.466	-.803	-.019									
	[SUVScheduleBehind=1]	.573	.920	.253	.186	.186									
	[SUVSchedulePressureReasonable=-1.00]	.238	.926	.845	.746	.741									
	[SUVSchedulePressureReasonable=1.00]	.003	-.625	-.981	-.465	-.393									
	[SUVSchedulePressureAggressive=-1.00]	.713	.335	.194	-.218	.030									
	[SUVSchedulePressureAggressive=1.00]	.512	.573	.196	-.140	.354									
	RT OT	-.418	-.175	.376	.362	.478									
	NumberSSHAComplete	-.346	.377	.739	.985	.366									
	NumberSSHAAudits	-.098	-3.024	-1.121	-1.471	-1.453									
	NumberInspections	-.212	-2.349	.035	-.416	-2.340									
	CapenterRT	-.855	-3.185	-.494	-1.301	-2.078									
	CapenterOT	.383	.600	1.055	.206	.653									
	CapenterJMRT	.704	.188	.127	.202	.760									
	CapenterJMOT	.039	.325	-.311	-.798	.323									
	CapenterFMRT	.019	.225	-.181	-.529	.197									
	CapenterFMOT	.116	.022	.544	.313	.230									
	CementFinisherRT	-.541	.560	.074	.507	.002									
	CementFinisherOT	.387	.350	.072	.706	-.013									
	ConcreteFinisherRT	-.361	.085	.582	.208	-.104									
	ConcreteFinisherOT	-.183	.398	.184	.215	.207									
	CraneOperatorRT	.540	.217	.450	.105	-.109									
	CraneOperatorOT	-.130	-.013	.153	-.013	.304									
	Craftsman2RT	-.443	.215	.025	-.273	.301									
	Craftsman2OT	-.069	-.490	.989	1.199	-.073									
	Craftsman3RT	.340	.387	.576	.227	-.003									
	Craftsman3OT	.195	-.707	.250	.585	.175									
	Craftsman3F1RT	-.593	-.555	.477	.458	.759									
	Craftsman4C1RT	.322	.726	.193	-.511	.527									
	Craftsman4C1OT	.240	-.771	.171	.503	.980									
	Craftsman4C2RT	-.057	.630	.021	.643	.307									
	Craftsman4C2OT	.224	.089	.559	-.216	.205									
	Craftsman4C3RT	-.136	.525	.651	.089	.419									
	Craftsman4C3OT	.067	-.168	.197	.384	.162									
	Craftsman4C4RT	-.101	.335	-.306	-.491	.127									
	Craftsman4C4OT	.419	.217	-.661	.351	-.300									
		-.433	-.001	.634	.205	.303									

	Craftsman5RT	.025	.080	.469	.220	.034									
	Craftsman5OT	.300	-.668	.244	.483	.846									
	Craftsman6RT	.064	.049	-1.117	-.524	-.657									
	ForemanRT	-.060	-.156	.385	.195	.098									
	ForemanOT	-.106	.187	.622	-.125	-.035									
	GeneralForemanRT	.067	-.263	-.528	-.138	-.220									
	GeneralForemanOT	-.105	-.831	-.325	.098	-1.162									
	LaborRT	.155	.152	.274	.588	.121									
	LaborOT	.287	-.019	-.017	-.192	-.337									
	LaborForemanRT	.312	.833	-.060	.436	-.166									
	LaborForemanOT	-.249	.240	.643	.199	.023									
	LeadHandRT	-.275	.186	-.649	.065	-.009									
	LeadHandOT	.299	.588	-.085	.352	.262									
	OperatorRT	.267	.818	.820	.345	.287									
	OperatorOT	.280	.244	-.004	.377	.211									
	SuperintendRT	-.244	-.461	.109	.509	1.106									
	SuperintendOT	.500	.329	.251	.444	.069									
	SupervisorRT	.001	.122	-.358	.348	.305									
	SupervisorOT	-.063	.480	.095	.045	.645									
	Supervisor1RT	.501	.183	-.209	-.182	-.119									
	Supervisor3RT	-.226	.316	.155	.029	.018									
	Supervisor3OT	.184	.605	.487	.653	-.006									
	SurveyorRT	-.231	.067	.156	.250	.818									
	SurveyorOT	.490	-.018	.149	.079	-.359									
	SUVHoursOfSafetyInteractions	-.450	.260	.069	.419	-.032									
	SUVPMTouringHRS	-.012	1.065	.179	.116	.417									
	SUVWorkerInspectionPercentage	.546	1.393	1.374	1.008	1.108									
	SUVWorkerInteractionPercentage	.230	-1.013	-.715	-.434	-.699									
	SUVJHandSMeetingRepresentation	.004	.427	-.164	.679	.540									
	SUVTimeOnSafetyDuties	.797	.851	.174	.171	.118									
	SUVNumberOfSafetyInteractions	-.184	-1.313	-.625	-.705	-1.404									
Hidden Layer 1	(Bias)						-1.212	-1.311	1.075	1.100	1.547	.988	1.018	1.331	1.080
	H(1:1)						-1.068	-1.139	2.131	1.346	1.625	1.867	1.219	1.613	1.461
	H(1:2)						.631	-.961	-3.103	-3.552	-1.378	-1.132	-4.128	-6.983	-5.707
	H(1:3)						-1.606	-.495	-1.109	-.558	-3.280	-3.041	-.287	.044	-.218
	H(1:4)						-.571	-1.007	-2.054	-1.328	-3.031	-3.253	-.636	.819	.341
	H(1:5)						.542	.096	-2.121	-2.728	-.669	-.316	-2.538	-1.393	-1.929

Parameter Estimates

		Predicted													
		Hidden Layer 1					Output Layer								
Predictor		H(1:1)	H(1:2)	H(1:3)	H(1:4)	H(1:5)	OLTI	ODaysLost	OMedicalAids	OFirstAids	OModifiedWork	OModifiedWorkDays	OAHazards	OBHazards	OCHazards
Input Layer	(Bias)	.795	-.290	-.110	-.124	-.074									
	[SUVProjectManagerLocation=-1]	1.050	-.622	.345	-.026	-.013									
	[SUVProjectManagerLocation=0]	.144	-.103	.065	-.107	-.180									
	[SUVProjectManagerLocation=1]	.096	-.461	.169	-.519	-.270									
	[SUVMentoring=-1]	-.713	-.197	.312	-.200	-.957									
	[SUVMentoring=0]	.183	-.232	-.021	-.475	-.455									
	[SUVMentoring=1]	.863	.948	.671	.921	1.053									
	[SUVTypeOfContract=CM@Risk (Guaranteed Maxim	.025	-.004	.411	-.002	-.117									
	[SUVTypeOfContract=Cost Plus	.463	.057	.151	-.194	-.542									
	[SUVTypeOfContract=LumpSum	-.581	-.933	-.246	-.682	-.399									
	[SUVTypeOfContract=Purchase Order	.374	.141	-.256	.277	.456									
	[SUVTypeOfContract=Unit Price	.761	.056	.128	.322	.040									
	[SUVScheduleAtProjectEnd=Ahead of Schedule	.133	.082	-.190	.200	.412									
	[SUVScheduleAtProjectEnd=Behind Schedule	1.010	-.221	.055	.512	.290									
	[SUVScheduleAtProjectEnd=On Schedule	-.105	-.445	.082	-.453	-.656									
	[SUVSchedulePriorToStart=Aggressive	-.263	.172	.304	-.368	.486									
	[SUVSchedulePriorToStart=Reasonable	.585	.208	.297	-.695	-.176									
	RT OT	.431	.274	-.050	-.392	.209									
	NumberSSHAComplete	.236	.114	-.156	.166	.241									
	NumberSSHAAudits	-.997	-.682	-.527	-1.543	-1.467									
	NumberInspections	-1.035	-.112	-.770	-1.417	-1.522									
	CapenterRT	-1.245	-.312	.027	-1.438	-2.240									
	CapenterOT	.243	-.204	.185	.066	.333									
	CapenterForemanRT	.170	.423	-.095	.545	.304									
	CapenterForemanOT	.264	-.011	-.106	-.068	.250									
	ConcreteAndCementFinisherRT	-.308	.019	.080	-.174	.525									
	ConcreteAndCementFinisherOT	.625	.030	-.481	.445	.737									
	SafetyOfficerRT	.366	-.731	.522	-.689	.154									
	SafetyOfficerOT	-.268	.343	-.412	.241	-.257									
	CraneOperatorRT	-.147	-.118	-.487	.000	.069									
	CraftsmanRT	.011	.367	-.352	-.478	-.562									
	CraftsmanOT	-.339	.294	-.219	-.229	.083									
	ForemanAndGeneralForemanRT	-.208	-.423	.331	.568	-.236									
	ForemanAndGeneralForemanOT	-.632	-.907	-.291	-1.929	-1.673									
	LaborRT	-.985	-.799	-.273	-1.155	-1.139									
	LaborOT	.832	.563	.169	-.213	.297									
	LaborForemanRT	-.153	.061	-.226	.362	.264									
	LaborForemanOT	-.111	-.218	.057	.214	.021									
	LeadHandRT	-.103	.320	-.195	-.071	-.629									
	LeadHandOT	.669	.180	.397	.071	-.458									
	OperatorRT	.396	-.166	-.498	-.337	.253									
	OperatorOT	-.393	.538	.652	-.104	.247									
	SuperintendRT	.469	.304	-.614	.150	.639									
	SuperintendOT	.125	.068	.599	.324	-.704									
	SupervisorRT	.092	.265	-.118	.211	-.163									
	SupervisorOT	.154	.188	.254	.738	.361									
	SurveyorRT	-.282	.385	-.288	.037	.116									
	SurveyorOT	.399	-.329	-.280	.029	.610									
	SUVPMTouringHRS	-.233	.198	.454	.217	.067									
	SUVWorkerInspectionPercentage	.890	-.084	-.161	-.412	.557									
	SUVWorkerInteractionPercentage	.550	-.027	-.038	-.167	-.170									
	SUVJHandSMeetingRepresentation	-.205	-.281	-.070	-1.258	-1.125									
	SUVTimeOnSafetyDuties	.322	-.316	.475	-.180	-.428									
	SUVNumberOfSafetyInteractions	.805	.233	-.108	.352	.821									
	SUVHoursOfSafetyInteractions	-.182	.038	-.612	-1.247	-.844									
Hidden Layer 1	(Bias)	-.080	-.159	.139	.110	.365									
	H(1:1)						-1.246	-2.390	-1.728	-1.408	-1.087	-2.409	-.983	-.773	-1.670
	H(1:2)						-.531	-.537	-1.008	-1.022	-.809	-1.217	-.929	-1.381	-1.369
	H(1:3)						-.042	-.890	-.603	-.633	.046	-.489	.055	-.557	-.507
	H(1:4)						-.638	-1.197	-.911	-.212	-.323	-.756	-.834	-.489	-.565
	H(1:5)						-1.405	-1.686	-1.538	-1.612	-1.262	-1.512	-1.210	-.908	-.911
							-.372	-2.086	-1.692	-1.204	-.846	-1.076	-1.430	-1.308	-1.644

Parameter Estimates

Predictor		Predicted													
		Hidden Layer 1					Output Layer								
		H(1:1)	H(1:2)	H(1:3)	H(1:4)	H(1:5)	OLTI	ODaysLost	OMedicalAids	OFirstAids	OModifiedWork	OModifiedWorkDays	OAHazards	OBHazards	OCHazards
Input Layer	(Bias)	1.582	.850	-.890	.941	.829									
	[SUVProjectManagerLocation=-1]	1.194	1.331	-.119	.667	1.177									
	[SUVProjectManagerLocation=0]	.069	.319	.099	.141	.366									
	[SUVProjectManagerLocation=1]	-.680	-.628	-.059	-.924	-.087									
	[SUVMentoring=-1]	-1.256	-.849	-.144	-1.250	-.680									
	[SUVMentoring=0]	.412	-.346	-.594	-.544	-.673									
	[SUVMentoring=1]	2.449	1.447	-.636	1.245	1.757									
	[SUVTypeOfContract=CM@Risk (Guaranteed Maxim]	.683	-.647	-.112	-.091	.551									
	[SUVTypeOfContract=Cost Plus]	.997	.757	.322	.358	.084									
	[SUVTypeOfContract=LumpSum]	-1.290	.040	-.363	.286	-.515									
	[SUVTypeOfContract=Purchase Order]	.242	.148	.036	.126	.844									
	[SUVTypeOfContract=Unit Price]	.019	.205	.419	.101	1.036									
	[SUVScheduleAtProjectEnd=ahead]	.323	.190	.038	.880	.086									
	[SUVScheduleAtProjectEnd=Behind]	.625	.897	.142	.525	.904									
	[SUVScheduleAtProjectEnd=On Schedule]	-.798	-.157	-.961	-.237	-.835									
	[SUVSchedulePriorToStart=Aggressive]	.327	.649	.093	.263	-.130									
	[SUVSchedulePriorToStart=Reasonable]	1.021	.725	-.228	.572	.215									
	RT	-.532	.538	.089	.377	.522									
	OT	.339	-.221	-.423	.603	.305									
	NumberSSHAComplete	-3.033	-.978	.060	-1.592	-2.897									
	NumberSSHAAudits	-2.427	-1.881	-.183	-.725	-2.820									
	NumberInspections	-3.214	-1.690	.235	-1.898	-2.650									
	TradeRT	.235	-.166	.198	-.582	.339									
	TradeOT	.466	.302	.203	-.171	.058									
	SupervisorRT	-1.021	.430	.410	.232	.267									
	SupervisorOT	-.165	-.662	-.068	-.539	-.386									
	SUVPMTouringHRS	.730	-.205	-.131	.559	-.169									
	SUVWorkerInspectionPercentage	1.359	.313	-.303	-.256	.770									
	SUVWorkerInteractionPercentage	-.793	-.585	.055	-1.105	-1.448									
	SUVJHandSMeetingRepresentation	.177	.590	-.555	-.246	.046									
	SUVTimeOnSafetyDuties	1.109	-.091	.438	1.049	1.386									
	SUVNumberOfSafetyInteractions	-1.083	-1.288	-.379	-.620	-.500									
	SUVHoursOfSafetyInteractions	.888	.179	-.383	-.152	.904									
Hidden Layer 1	(Bias)						-1.510	-2.282	.277	-.111	-.845	-.217	.283	.944	.316
	H(1:1)						.092	-.728	-2.057	-1.893	-.489	-.393	-2.053	-3.055	-2.708
	H(1:2)						-.100	-.982	-1.062	-.518	-.787	-1.149	-.937	-.027	-.029
	H(1:3)						-.747	-.047	.021	.157	-.028	-.396	-.162	-.147	-.493
	H(1:4)						-.686	-1.554	-.855	-.931	-.908	-1.091	-1.044	-.301	-.201
	H(1:5)						-1.334	-1.270	-.772	-.854	-.911	-.585	-1.369	-1.747	-1.751