AN INTERACTIVE DIGITAL MANUAL FOR SAFETY AROUND CONVEYOR BELTS IN SURFACE MINING

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Abstract

Belt conveyor accidents are mainly attributed to negligence of safety procedures during maintenance work. Entanglement, falling from heights, & collapse of structure or loose materials are the main cause of accidents. While performing maintenance tasks such as cleaning, installation and repair, belt alignment and so on (Lucas et. al. 2007).

Current industry safety programs provide general guidelines for safety training, but do not require any specific training program structure (Shultz, 2002 and Shultz, 2003). For example MSHA (Mine Safety and Health Administration) only requires 24 hours of training. Typically this training is broken down into four hours of training before the employee starts work, the remaining 20 hours has to be performed within the first sixty days of work (Goldbeck, 2003). The information collected through site visits showed that in addition to completing MSHA safety training requirements companies try to reinforce safety issues through daily and weekly safety meetings on job sites. Due to lack of a required safety training structure, every company is independent in terms of their training format that they follow to train their new and experienced work force. As a result, safety engineers depend heavily on in-house safety programs (e.g. audio-video presentations) to deliver the required training hours specified by MSHA for miners.

Based on a review of current training methods this research identifies four problems; existing training methods to educate miners about dangers involved in conveyor belt environments are mainly passive, safety related information in scattered in various media such as images, videos, paper manuals, etc., access to information in current format is difficult, and updating information is difficult.

This research addressed these identified problems by devising a new approach of learning to augment existing methods of training and evaluate the potential of this concept as a safety-training tool. Research has shown that individuals have their own learning style in which they can increase their retention and stimulate their cognitive learning. The proposed work addresses issues relative to passive vs. active learning and classroom-based vs. self-paced training by developing and implementing an interactive multimedia-based safety-training tool called the Digital Safety Manual (DSM). After the DSM was developed it was put through a series of usability evaluation and subjective analysis to measure the potential of the concept. The evaluation and subjective analysis involved both the novice and expert users.

The results that were yield after the evaluations and subjective analysis shows that the DSM has more learning advantages than the typical training methods and it can be used as a supplementary training method to complement the current approaches of training.

[*This research is being developed with support of pilot grant from Center for Innovation in Construction Safety and Health at Virginia Tech.]*

Dedications

I dedicate this dissertation to my family, past, present and future. Thanks for all your support.

Additionally, I dedicate this dissertation to my friends who encouraged me and occasionally made me tasty home-cooked meals to help keep me going during late nights of work.

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Chapter 1: Introduction

1.1 Background

The mining industry is characterized by the need for high volume of production, which has forced its adoption of large and fast moving equipment for transporting bulk material. Belt conveyors have attained a dominant position in transferring material due to such inherent advantages as their economy of operation, reliability, versatility, and practically unlimited range of capabilities. In surface mining, conveyor belts are of prime importance due to the nature of the mining operations and are the cause of many fatalities as they involve large number of moving machinery parts.

Belt conveyors come in various configurations; however, the basic components of the conveyors are the same. They can be at level or inclined, and are usually set up in a series of multiple conveyor runs. With the basic operation of a belt conveyor, the material is loaded onto the belt near a tail pulley and unloaded near a head pulley (or drive end). Between the head and tail pulleys are a series of idlers and pulleys to keep the tension and alignment of the belt, and to help prevent excessive wear (Figure 1). Belt conveyors run continuously without loss of time for the loading and unloading, scheduling, and dispatching that haul trucks and other equipment require. They typically run at 600 feet per minute and only need to be stopped for maintenance. Belt conveyors also often offer the lowest transport, maintenance, power, and labor cost per ton of material moved with a larger capacity to operation time ratio than other material moving equipment (Swinderman 2002).

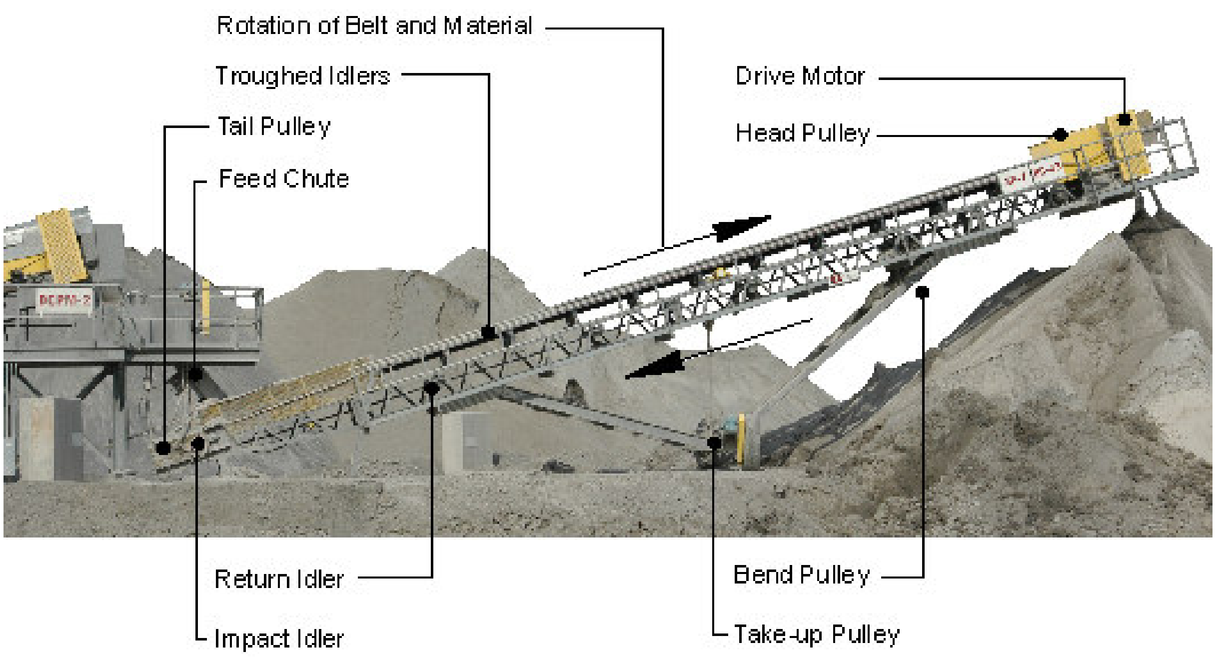

Figure 1: Conveyor belt components (Lucas, Thabet, & Worlikar 2008)

By their very nature, belt conveyors are inherently dangerous as a work environment. Due to the continuous moving parts and high rate of materials transported, the forces applied by conveyor belts are significant and potentially dangerous. Conveyors also feature many “pinch” points with large amounts of mechanical energy (see Figure 2). As the name suggests, pinch points form areas between the moving conveyor parts (e.g.

cylinders) and belt where miners can get entangled or pulled during performing maintenance tasks. As a result, they have a high rate of injury. Nevertheless, belt conveyors have become a "part of the landscape; they are not seen as hazards, but rather as a fact of life" (Goldbeck, 2003). It is imperative to be aware of the power of a conveyor while performing operations and maintenance as it has potential to injure or kill an untrained or unaware individual.

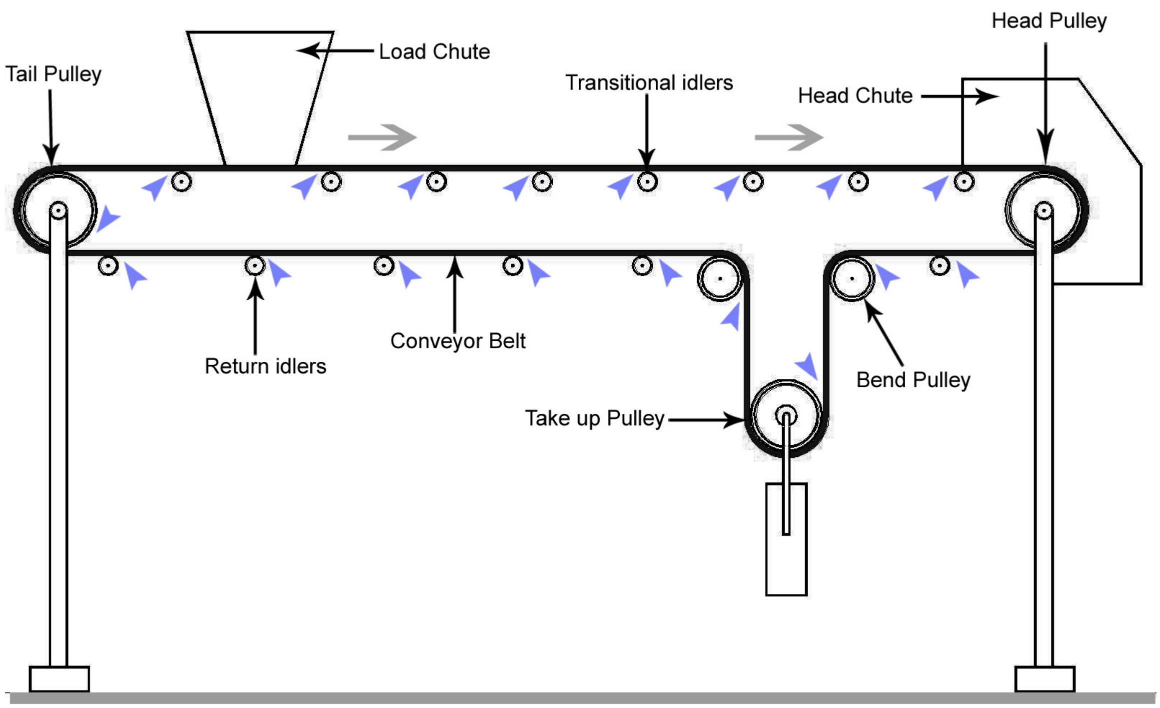

Figure 2: Schematic diagram showing conveyor belt components and pinch points (Lucas, Thabet, & Worlikar 2007)

Mine Safety and Health Administration (MSHA) shows there were 50 fatalities that involved conveyor belts since 1995-2007 (Lucas, et.al. 2008, Lucas, and et.al 2007). This analysis shows that the age of miners involved in these fatalities ranged from 18 to 64 years old and experience ranged from 2 weeks to 45 years. This implies that the age and experience of the miners is not a factor that contributed to the accidents. Each year there are numerous injuries, serious and fatal, that occurs around belt conveyors because of inadequate training and due to ignorance of the miners. This costs millions of dollars to mine operations each year. Goldbeck (2003) also reported that the cost of a fatality in a mine was estimated to be $1.02 million in 1986 ($1.9 million in 2007 according to US Bureau of Labor Statistics inflation value (www.bls.gov). This value was calculated by considering medical expenses, worker's compensation, accident investigation, loss of family income, and lost production value. The same study estimated permanent disability accidents of less severity at $237,000 and each lost-time accident at an average of $5,000 (Goldbeck, 2003). These statistics are the basis of research leading to the development of a new approach for safety-training program for belt conveyors (Lucas and Thabet 2007).

Most of the accidents around belt conveyors are caused by human error, improper maintenance procedures, lack of effective training or lack of awareness of possible hazards. In CFR Part 46 and 48, MSHA requires training for all miners (Goldbeck, 2003). Newly trained workers must receive 24 hrs of specified training. An additional 8 hrs of refresher training is specified each 12 months. No specific training on belt conveyors is mentioned. Based on the number of conveyor related accidents and fatalities (MSHA 2007), it is evident that current required training that are based on standard audio-visual methods, are not effective in achieving their goal.

Current training in the industry to understand conveyor belts and their safety is mainly the responsibility of the owner/operator of the mining facility. Both OSHA and ANSI classify conveyor belt safety into the general operational and safety training. They place the responsibility of training on the owner to use a certified, qualified and competent person to train the operators. Based on the information provided by the industry experts, even though there are no educational qualifications required to be a safety trainer some companies require their miner to have high school diploma. The minimum age requirement to be able to work in a mine is 18 years till the time he is in relatively good health. The most important factor to be a safety engineer is to have sufficient experience and be able to deliver the training material in an effective way.

Often times, this leads the owner of the mine to appoint a safety engineer. The common practices of training within the mining industry for conveyor belts are to incorporate the basic safety and awareness into videos and slide shows that are shown for required general safety training. The interviews that were conducted also show that every company has its own way of emphasizing importance of safety by having the weekly safety meetings. These meetings cover any new site specific hazards, the informal safety talks would consist of talking about near misses and prevention whenever safety staff thinks it's relevant, and lastly, the rewards and incentive programs are of both monetary reward and activity rewards.

The primary motivation in conducting this research project is to devise a new approach to augment existing training methods. This would raise the level of training through self-learning and eventually reduce safety violations and minimize fatalities. Multimedia based training applications can be an effective tool for safety training to augment traditional training methods. Such applications can enhance the cognitive learning skills and information retention ability (Worlikar and Thabet 2008).

The training methods that are practiced in the industry today are passive and need to be revised to provide more pro-active methods of learning the subject matter. This research work addresses the issues that currently exist in the mining industry by developing supplemental training applications to reinforce the importance of safety can result in fewer fatalities per year.

. The initial part of this research (data collection) was part of a research program that is being developed at Virginia Tech (funded by a NIOSH Grant # 1 R01 OH008716-01) to investigate the effectiveness of VR for training of personnel working around conveyor belts in the surface mining industry. The program involves developing a series of instructional-based and task-based VR modules that are intended to assist the user in understanding the components and assemblies of the conveyor belt, explain the different hazards and safety issues associated with moving belt components when performing maintenance, and test the user's ability on resolving problems while performing a required set of pre-defined tasks in the VR environment.

The idea for the DSM was conceived during the data collection phase of the above mentioned funded research at Virginia Tech. and further research to develop the DSM was funded by the Center for Innovation in Construction Safety and Health at Virginia Tech. Initially the intention of the DSM was to develop a single repository to store all the safety related information but later on as the research progressed the scope of the research widened to develop a new approach to deliver the training material in a non-interactive self-paced environment.

1.2 Problem Statement

Based on a review of current training methods discussed in the introduction, four shortcomings are identified:

***<u>Problem #1:</u>* Existing training methods to educate miners about dangers involved in conveyor belt environments are mainly passive.**

The traditional methods of training are conducted in a classroom-based environment where the trainer delivers the information to the trainees without actively involving them in the process. Such passive methods of educating miners using mainly Power Point presentations in a classroom environment need to be revised to provide more pro-active methods of learning the subject matter. Research shows that less than 15% of the material covered in the classroom or corporate training room ever gets applied to the job (Broad and Newstrom 1992). The researches in cognitive science field have proven that by involving actively in the learning process enhances the process of acquiring knowledge and understanding through thought, experience, and the senses.

The focus of educating and training is shifting to learning by actually doing the task (unstructured approaches) as apposed to just listening in the classroom based training sessions structured approaches). A pro-active non-linear and self-paced approach can enhance retention of information.

Also, the current generation of experienced miners is approaching retirement and there is need to transfer their knowledge (experience) to the younger generation quickly and in mass.

***<u>Problem #2:</u>* Current safety related information is scattered in various media such as images, videos, paper manuals, etc.**

There is no concise data bank for all the information related to the safety around conveyor belts. All the information is scattered in various medias such as paper handouts, loose pictures, overhead projector slides, paper manuals, videos, etc. and stored in the library of the office. So the browsing and referring of information is limited to the work/office environment and training sessions.

Capturing and storing multimedia (pictures, videos, textual information) data in a databank that allows for comprehensive browsing and ease of referring.

***<u>Problem #3:</u>* Easy access to information in current format is difficult**

The information that is available in current format is not always accessible to the workers. The access is dependent on the two things; availability of all the scattered information in current format (videos, photographs, paper manual) and work environment. If workers want to refer to the information they have to access it while they are in the office. Accessibility of the information is not flexible.

Digitized information can be made accessible through World Wide Web or CD-ROM, Personal computers, PDA's, etc.

***<u>Problem #4:</u>* Updating and modifying the existing safety information is difficult**

Updating the information in current format is difficult to keep up with and it solely depends on the safety engineer/trainer to update the information from time to time. Also, storing and maintaining the inventory of the photographs and videos and other paper manuals becomes cumbersome.

Digitizing the information allows for ease of update and modifications. It also allows adding large amounts of information.

1.3 Research Objectives

Following are the objectives of this research work that addresses the above identified four problems:

Objective #1: ***Devise a new approach of learning to augment existing methods of training to respond to some of the shortcomings of the current training methods.***

This objective involves:

- Capturing, storing, and classifying safety information into a format accessible through self-paced interactive approach.
- Implementation of the Digital Safety Manual (DSM) prototype; a multimedia-based tool for representation and navigation of the information using a three dimensional graphical layout.

This objective is achieved by documenting and implementing the DSM prototype; a 3d graphical layout, that addresses the four identified problems; existing training methods are passive, current safety related information is scattered in various media, easy access to information in current format is difficult, and updating and modifying the existing safety information is difficult.

The new approach (i. e. the DSM) addresses these four problems by allowing learning by doing or actively involved in the process, easy accessing of the information, a single repository for all the safety related information, and allows easy updating the information.

The DSM also addresses the problem of retirement of the current generation of experienced miners by devising new approach that is more attractive to the younger computer savvy generation. Experienced miners would be part of content development process and to train the younger workforce.

Objective #2: ***Evaluation of potential of the DSM Prototype.***

This objective involves putting the DSM prototype through an evaluation. The evaluation scheme is divided into two phases:

1. Usability evaluations, and
2. Subjective Analysis

The usability evaluations are intended to get feedback on navigational issues, user interface related issues, and information review from industry experts. This phase included both the novice (VT students) and expert users (industry experts from three mine operations in Virginia are).

The second phase is subjective analysis using qualitative and quantitative approach to test the potential of the tool compared to other training method. This phase also involved both the novice (VT students) and expert users (industry experts from the three mine operations in Virginia area).

This objective will determine the validity and the potential of this concept of using the DSM as a supplementary training method.

1.4 Research Methodology

This research is divided into following four stages:

1] Data Collection:

This stage was focused on collecting available safety information for belt conveyors by using various resources such as;

- Multiple site visits: By conducting interviews with mining companies/industry partners to gather information.
- Pictures: By taking pictures of various belt components, conditions, and general belt environment to create an image databank.
- Videos: Capturing videos of various workings and conditions of belt conveyors.
- Literature review: Gathering information by doing an extensive literature review and publications
- Other sources: By purchasing training material from recognized sources.

2] Data Classification:

A data-grouping framework is designed to classify safety information and the four main categories were defined. The framework comprises of four main categories; *Belt Conveyors, Possible Hazards, Preventive Measures,* and *Awareness & Statistics. Figure 3 shows the four main categories and their sub-categories.*

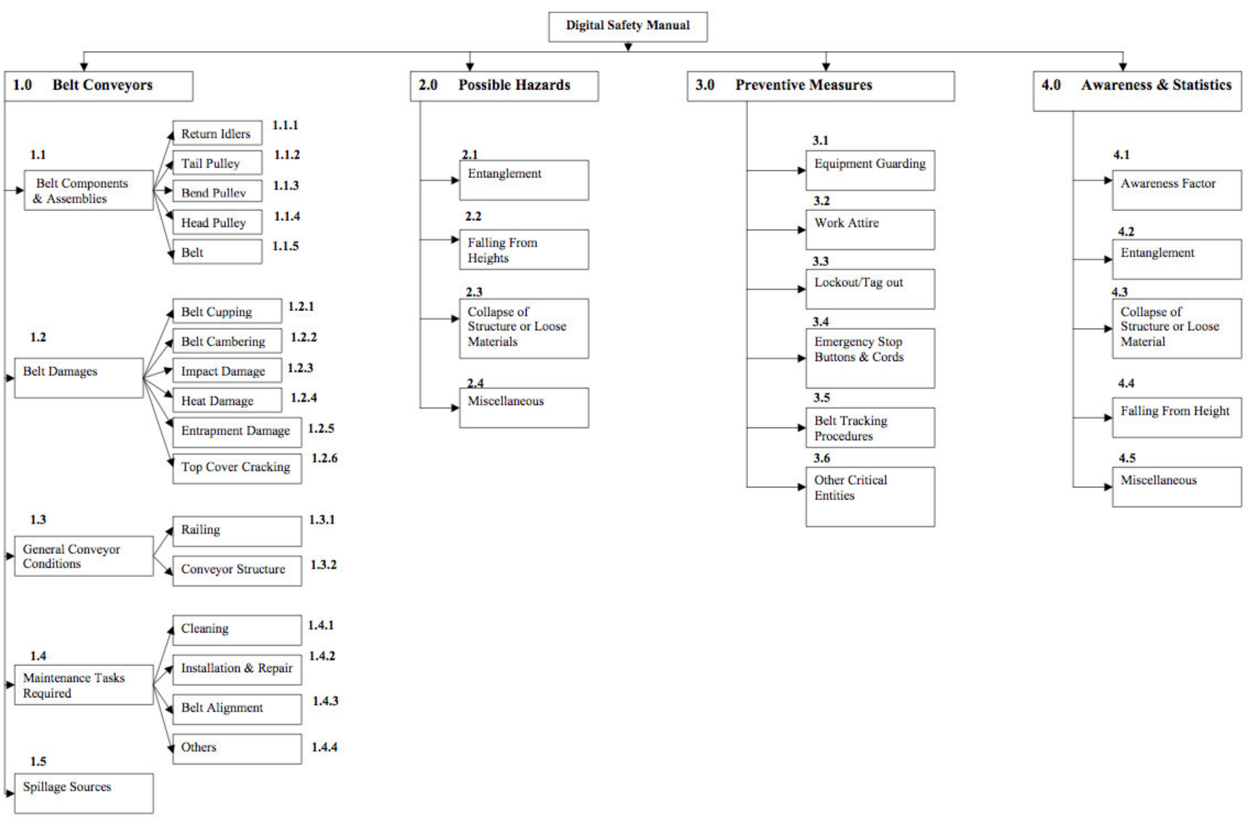

Figure 3: Hierarchical Categorization of the Information in the DSM

Category 1.0 Belt Conveyors:

This category focuses on general information about conveyors and belt conditions and this level further divide into five sub-categories. These sub-categories are:

- Belt components and assemblies such as return idlers, tail pulley, bend pulley, etc.
- Recognize belt damages like belt cupping, belt cambering, impact and heat damage, entrapment damage, etc.
- Recognize general conveyor conditions like broken railing or damaged conveyor structure
- Maintenance tasks required such as cleaning, installation and repair, belt alignment, etc.
- Recognize spillage sources. This category is expected to give basic understanding of the knowledge about conveyors, its components and tasks that one might have to perform while working around conveyors.

Category 2.0 Possible Hazards:

This category deals with the possible hazards related to conveyor like entanglement, falling from height, collapses of structure or loose material, and others. These sub categories are derived after analyzing 50 conveyors related accidents from 1995-2007 listed on msha website (www.msha.gov). Within this category the user will interact with above-mentioned four sub categories to learn more about them through digital images, videos, and general description of individual hazards.

Category 3.0 Preventive Measures:

This category contains information about general safety practices while performing maintenance and further sub divides into seven sub categories. Intention of this category is to educate the user about safety measures that need to be taken while performing work around conveyors. These safety measures include:

- Equipment guarding,
- Proper work attire,
- Lock out/tag out procedures,
- Belt tracking procedures,
- Emergency cord and stop buttons, etc.

This category helps the miner in understanding the importance of practicing proper safety measures while performing work around conveyors.

Category 4.0 Awareness & Statistics:

The research analyzed 50 recordable fatalities listed on the Mine Safety and Health Administration (MSHA) website around conveyor belts from 1995-2007. The fatalities were analyzed and categorized by the cause of accident, components contributing to fatality, types of maintenance tasks performed during accidents, etc. This statistical information is collected from www.msha.gov.

This category also emphasizes on the awareness factor by providing real life incidences and interviews of the killed/injured worker's family members. The human factor of safety is emphasized in this section.

3] Digital Safety Manual Implementation (Prototype Development):

A prototype of the Digital Safety Manual (DSM) will be developed to provide an effective/logical way to show relationships between the related information within the four categories (Worlikar 2008). The digital matrix uses a 4 x 4 grid to store content and provide user the necessary navigational tools to explore the Digital Safety Manual (see Figure 4). Every square tile in this grid contains inter related information and the four diagonal square tiles serves as main navigational nodes to move back and forth in the matrix.

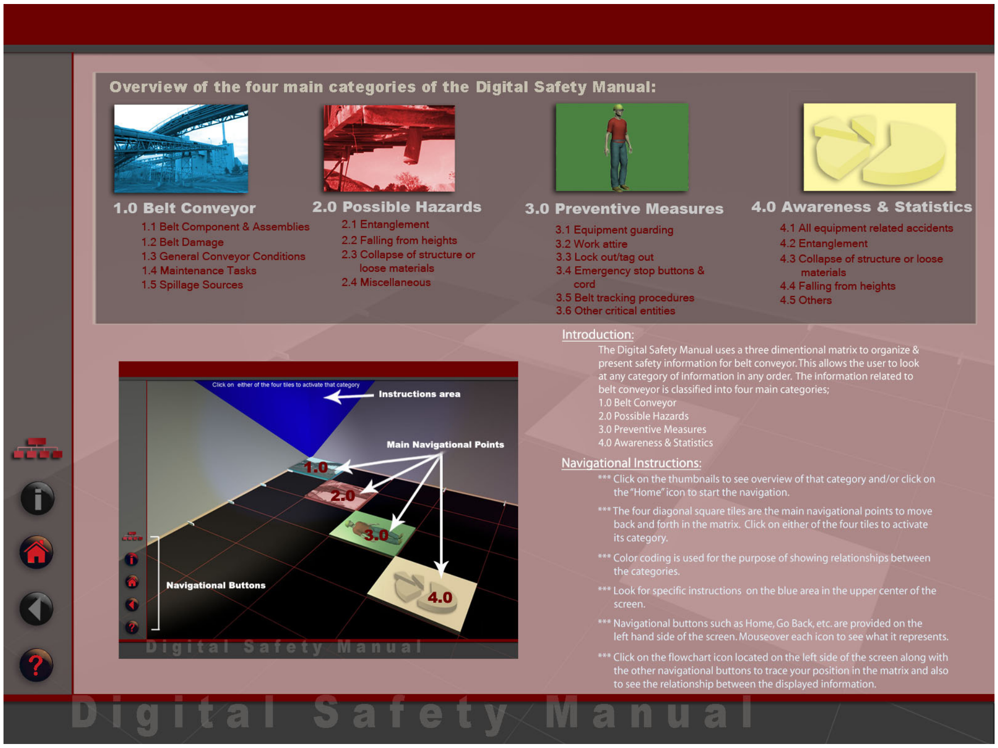

Figure 4: The into screen of the Digital Safety Manual

Upon activating any of these four square tiles by clicking on them will bring up the information bars representing sub-categories within the selected category (see figure 5). The height of these bars symbolizes the amount of information that it contains. If there is further bifurcation within the sub-categories then the sub-category bars will be further divided into sub-components of information. Each category bars are color-coded as well to provide the visual link/grouping between the information when it appears at different points in time on the surface of the grid. The color-coding draws the link between the related information and helps the user to correlate the information that is presented with the same color square tile. This allows effective accessing and browsing of the content in a collection.

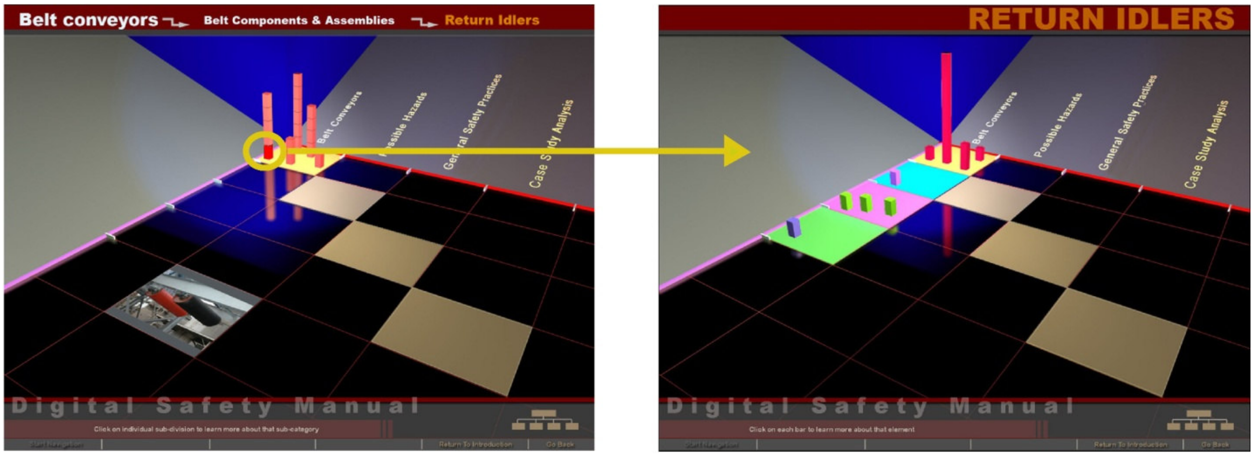

Figure 5: 3D matrix showing combination for Return Idler component. (Lucas et. al. 2008)

This prototype was developed by using Macromedia's Director and 3D Studio Max. Macromedia Director allows bringing in different medias together and assigning an element of interactivity to it. The DSM provides safety related information for belt conveyors through images, videos, text, and animations.

4] Evaluation Scheme:

Once the proposed DSM application was developed it becomes important to verify that it meets the industry's needs for learning and for its content, accuracy and consistency of the presentation (Lucas et. al 2008).

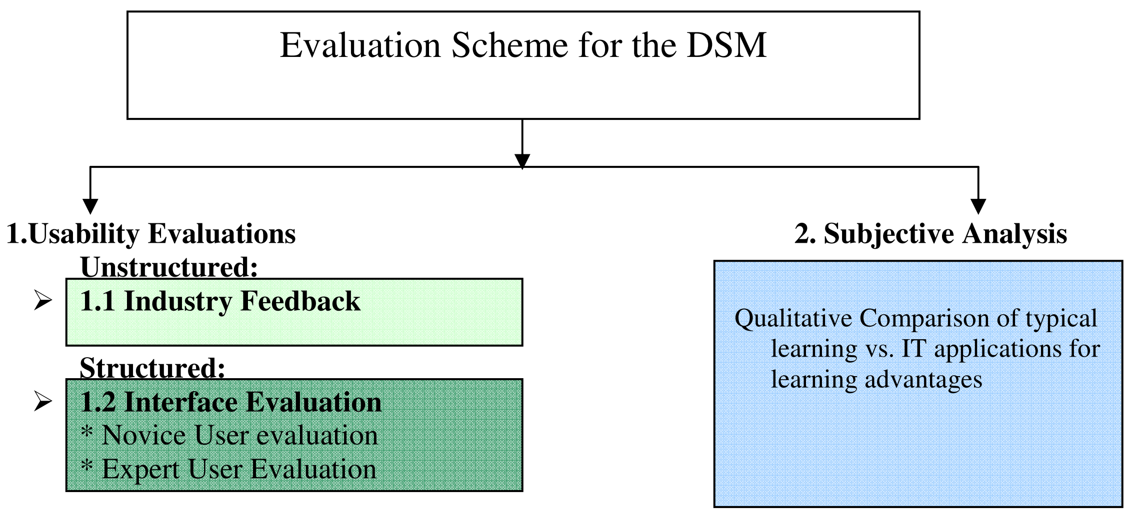

Figure 6: Evaluation Scheme for Usability Evaluations (pilot study) and Subjective Analysis

In order to accomplish this, the application was put through a series of feedback and usability evaluation (pilot study) phases to validate the new approach of training (see Figure 6).

The master scheme (see Figure 6) is divided into two major phases: usability evaluations and the subjective analysis during which the application was updated to a new iteration based on the comments and reviews that we received. The scope of this research was to subjectively analyze the potential of the DSM concept as oppose to objectively prove the effectiveness of this new learning approach.

Data Analysis

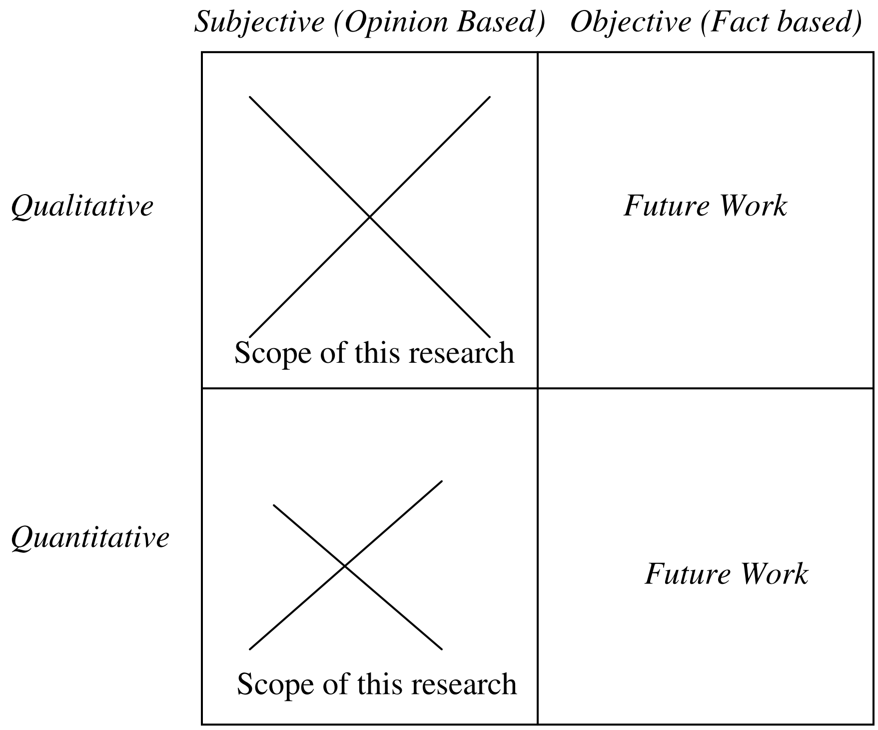

Figure 7: Data analysis table

<u>Usability evaluation stage is divided into two sub-phases;</u>

- Industry Feedback (Unstructured): This stage was focused on getting feedback on information presented in the DSM from the industry experts.
- Interface evaluation (Structured): This stage conducted interface usability evaluations using novice users (graduate students) and expert users (industry partners)
    - Novice users (Content deprived): This group was used to evaluate usability issues such as navigational controls, completeness and correctness of the application, information presentation issues, etc. by asking them to fill out a questionnaire at the end of their exploration of the DSM.
    - Expert users: This group was used to evaluate usability issues along with the appropriateness of the presented information and for its completeness and correctness by using similar but more content oriented questionnaire.

<u>Subjective Analysis:</u>

This part of the evaluation scheme used two groups of users (novice and industry experts) to compare the traditional methods versus IT based safety training applications for the learning advantages (DSM). The subjective analysis was done to prove the concept of the DSM as oppose to measure the user's performance based assessment.

- Group 1 (Novice users): This group was presented the information by simulating the traditional methods of training delivery such as verbal presentations, slideshows, videos, and safety documents. After the group was exposed to the traditional training methods, the same group was given a demonstration of the DSM covering the similar information as covered in the traditional training method. Once the group was exposed to both the training methods they were given a survey to fill out to qualitatively compare both the training methods. This survey asked questions like What are some of the advantages of a typical training method you are familiar with over the reviewed application?, What are some of the advantages of the reviewed prototype application over the typical training?, What features of the reviewed application do you see as the most beneficial for learning the training material?, etc.
- Group 2 (Expert users): This group was given a demonstration of the DSM to explain the concept of self-paced interactive training. Since this group comprised of industry experts (safety engineers, superintendents) and are already familiar with the traditional method of training methods, so skipped that part of the comparison survey procedure. Industry experts were also asked to fill out same survey as novice users to compare the new application and traditional training methods.

After the evaluation of the application was completed, all the suggestions, comments, and findings were reviewed, analyzed and documented to validate the objectives of this research work.

1.5 Research Limitations:

The scope of this research work included the following two things:

1. *Develop & Implement the DSM concept:*

Develop and implement the concept of the DSM showing four examples from each of the four main categories. Following were the four developed examples:

- Category 1.0 (Belt Conveyors): 1.1.1 Return Idlers
- Category 2.0 (Possible Hazards): 2.1 Entanglement
- Category 3.0 (Preventive Measures): 3.1 Equipment Guarding
- Category 4.0 (Awareness & Statistics): 4.1 Entanglement 4.2 Awareness

2. *Evaluate the DSM:*

The evaluation of the DSM was limited to the subjective analysis as oppose to the objective analysis. The reason for conducting the subjective vs. objective analysis was to prove the concept of the DSM based on the developed prototype instead of analyzing the user performance after using the developed application.

1.6 Thesis Organization:

This research work is organized in chapter format to present the information and the outcomes achieved as a methodology for final thesis submission. Thesis is organized as follows:

Chapter 1: Introduction

This chapter gives overview of the research work by identifying the problems that currently exists in the training methods. This chapter also states the objectives of this research and proposes the research methodology used. Later part of this chapter covers limitations of this research and also describes the organization of the thesis book.

Chapter 2: Background and Literature Review

This chapter looks at the fatalities related to the conveyor belt from MSHA since 1995-2007 and statistics reported by other authors. It also introduces the current training methods that are being used in the industry and states the training requirements by MSHA & OSHA. Later on in this chapter the need for a training method is identified and proposes a safety training structure.

Chapter 3: Data classification and Description

This chapter informs the reader about the classification and categorization of the data that was collected during the data collection stage.

Chapter 4: Benefits of Multimedia-based learning environment

This chapter talks about the different advantages of the multimedia-based learning environments and identifies four dominant benefits of the multimedia-based learning environments: enhanced cognitive learning skills, learning by actively participating in learning process, increased motivation, and flexibility in terms of time and location.

Chapter 5: Research Methodology

This chapter discusses the methodology that was used to conduct this research work and developing the prototype of the DSM.

Chapter 6: Evaluations & Results

This chapter discusses the evaluation scheme, the process of evaluation, and the quantified results of the evaluations.

Chapter 7: Limitations & Future Work

This chapter discusses the limitations of this research work and based on those limitations proposes the future work.

Chapter 2: Background & Literature Review

2.1 Data Collection Process

Data collection process was done in two steps; in first step the data was collected through literature review and in step two the data was collected through various site visits to local mine operations. The main focus of data collection was aimed towards finding out other sources and researchers who have reported accident statistics related to belt conveyors, safety training requirements by OSHA, MSHA, ANSI, current safety training practices, and safety training structures proposed by other researchers. Primary source for literature review was the Internet, publications, and books. Along with the statistics reported by Goldbeck (2003) (see section 2.2) 50 fatalities reported to MSHA were also studied, analyzed, and complied (see section 2.3 and Appendix A).

Step two involved multiple site visits to three mine operations (Roanoke Cement, Boxley Blue Ridge, and LuckStone in Virginia). During these site visits interviews with the industry professionals were conducted to gather information related to belt conveyors. During these meetings questions were asked to verify the information that was collected through literature review using various sources for its accuracy and to collect additional critical information that can be only known to mine operators. These meetings were recorded and then documented so that it can be used during the development and implementation phase of this research work. During these site visits information was documented in the form of digital images and videos of the actual belt conveyor assembly and its components in mine environment. The information database in terms of general information, digital images and videos, etc. was updated after every site visit so that it can be used as a databank during development of the prototype application to demonstrate the concept of this research work.

2.2 Accident Statistics from Literature Review

No matter how innovative, sophisticated, specialized, or foolproof the technology, its long-term performance is governed by the human element. Between 1996 and 2000 there were 459 reported injuries ranging from fatalities to injuries with restricted work activities in surface areas of metal/non-metal mines in the US (MSHA 2007). Of these 459 reported accidents, 13 were fatalities and another 22 were reported as permanent disabilities. 42% of reported accidents occurred when the injured worker was performing direct belt maintenance. Another 39% occurred while the subject was cleaning and shoveling around the conveyors (see Figure 8). 290 of the 459 injuries and 10 of 13 fatalities have occurred due to working around moving conveyor belts and due to getting caught between moving conveyor belt and pulley (Goldbeck 2003). Since 1993 there have been 1024 mine fatalities, a frightening statistic that has shown mild signs of slowing since 2001, but still had 57 deaths in 2005 (MSHA 2007). The cause of the reduction of fatalities can be contributed to the recent success of research projects targeted specifically at mines and safety.

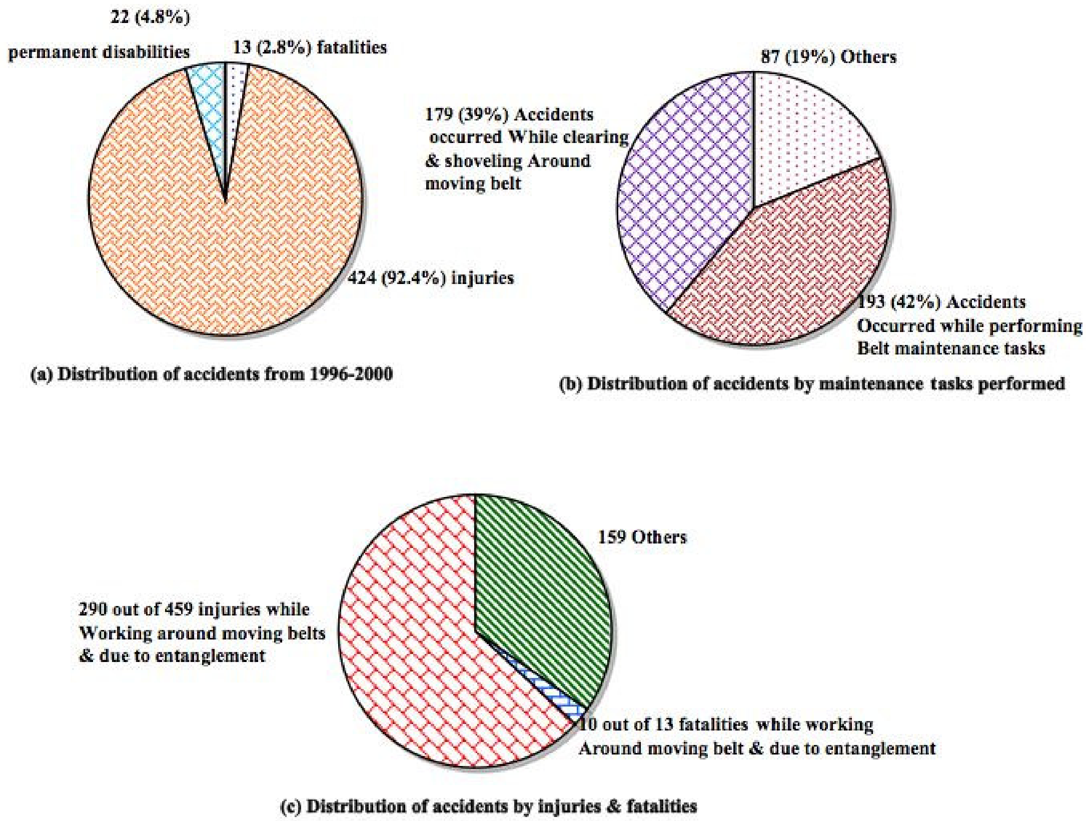

Figure 8: Statistical analysis of belt related accidents by Goldbeck between 1996-2000

Statistics from MSHA indicates that conveyor belts have been the cause of 50 fatalities since 1995 (3 in 2006). Total equipment related accidents accounts for 534 accidents since 1995-2007 out of which 50 are related to conveyor belts (MSHA 2007). The majority of these accidents happened due to performing maintenance tasks and operation around energized conveyor belt. It is also observed that the most accident-prone parts of the conveyor are return idlers, tail pulley, and the conveyor belt itself. Out of these 50 reported accidents 11 fatalities occurred on moving conveyor belt, 9 fatalities occurred due to entanglement between return idlers and moving belt, where as 7 accidents were related to tail pulley. Other notable hazards that caused deaths were materials falling from the conveyor (either crushing, or suffocating the victim), falling off of the actual large structures along the conveyor, crossing the conveyor where there is no crosswalk, and the actual structure of the conveyor itself failing and falling on the victim.

Few of these accidents occurred due to not observing proper work attire while working around moving conveyor belt. The fatalities statistics from 1995-2007 depending on the frequency of occurrences and related component of the conveyor belt are summarized in Figure 9.

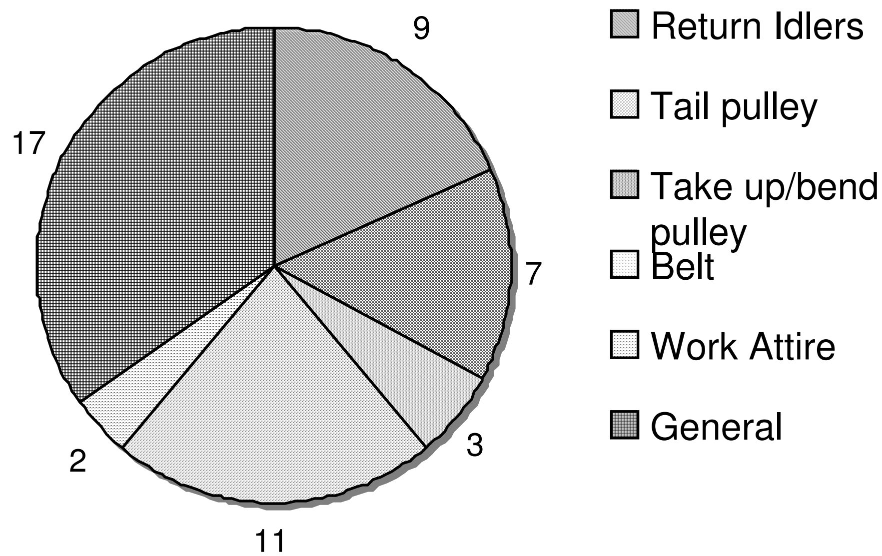

Figure 9: Conveyor belt related fatalities from 1995-2007 (MSHA) (Lucas, Thabet, & Worlikar 2007)

2.3 MSHA Reported Accident Statistics

Between 1995-2007 there have been a total of 534 fatal accidents in the surface mining that are equipment related, out of which 50 cases were associated with conveyor belts (MSHA, 2007). Research analyzed the 50 cases to identify the reasons for the accidents, and determine the type of maintenance tasks performed and their location around the belt when the accident occurred. A summary analysis is provided in Appendix A. The 50 reported injuries were grouped into four categories based on the cause of the accident; entanglement, collapse of structure, belt components or loose material (suffocating or crushing the victim), falling from heights, and miscellaneous. Within each accident category, analysis identified the type of maintenance task that was being performed when the accident occurred, and the belt assembly that contributed to the fatal injury were analyzed two of the factors, age and experience of the miners involved in the fatalities to see if either of the two factors are the root cause of the accidents. Analysis shows that a 57 years old miner can get killed after having 36 years of experience and at the same time an 18-year-old miner can get killed after having 2 weeks of experience (see

Appendix B). This analysis indicates that the age and experience of the miners is not the root cause of the accidents. Based on this analysis researchers believe that the existing training methods are inefficient or need improvement in training the workforce. Figure 10 provides a summary statistical analysis of the 50 cases showing distribution by accident category, by maintenance task category being performed while the accident occurred, by critical belt assembly contributing to the accident, and by year the accident occurred.

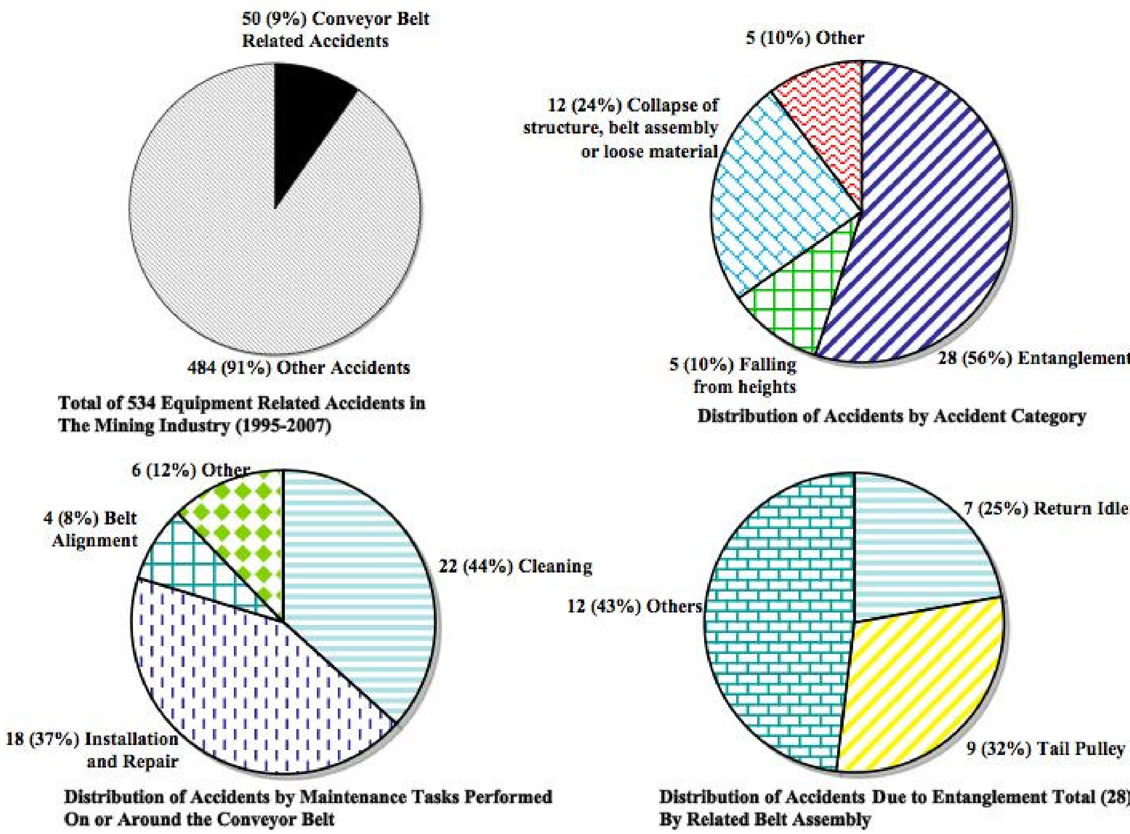

Figure 10: Statistical analysis of all belt-related fatal accidents reported by MSHA between 1995-2007

Analysis results by accident category show that the most common reported cause of accident around conveyors is due to entanglement between the victim's body parts, or his tools (e.g. shovels) and the conveyor assembly. This accounted for 28 (56%) of the 50 fatalities reported. Few of the entanglement incidents occurred due ignoring proper work attire. A second critical cause of fatal accidents included collapse of structures, belt assembly, or loose material falling off the conveyor, either crushing, or suffocating the victim. This contributed to a total of 12 fatalities (24%). Falling from height mainly off the elevated structures along the conveyor, or while crossing the conveyor where there is no crosswalk, resulted into 5 fatalities (10%). Other various reasons contributed to 5 fatalities (10%). Theses included burning, run over by service equipment and victim being crushed by belt assembly.

Four categories of maintenance tasks were identified from the cases:

- Cleaning around and under the belt and equipment to remove spilled debris accumulated on belt components or built-up on the floor under the belt. Cleaning was frequently done using small tools (e.g. shovel) or sometimes by hand.

- Installation and repair. This involved maintenance work for installing new or repair existing parts of the belt assembly (e.g. replace broken chain for belt drive motor) or the surrounding structure.
- Belt alignment
- Other. This included miscellaneous maintenance tasks such as inspection work, maintenance of large service equipment (e.g. loader) near the belt, and material sampling.

Distribution of accidents by maintenance task category indicated that cleaning of spillage and debris on and around the energized belt was the highest reported work performed when the accident occurred – 22 of the 50 accidents reported or 44%. Of these 22 accidents, 14 (73%) were a result of entanglement, and 7 (27%) occurred due to falling loose material and components crushing or suffocating the victim. Maintenance work involving installation and repair of the belt assembly or the surrounding structure contributed to 18 of 49 fatal accidents (36%). Four accidents (8%) occurred during maintenance work involving belt alignment. The remaining 6 out of 49 accidents (12%) occurred during performing other miscellaneous tasks.

Fatal accidents due to entanglement were analyzed to determine critical belt component contributing to the accident. Figure 2d shows distribution of accident by belt component involved. It is realized that the most critical parts of the conveyor assembly contributing to accidents by entanglement are return idlers, tail pulleys, and the conveyor belt itself. In total, 28 fatalities have occurred due to entanglement. 14 of these accidents were a result of getting entangled between an unguarded tail pulley (8 cases or 29%) or an unguarded return idler (6 cases or 22%) and the energized belt. An additional 14 accidents (48%) occurred as a result various other belt components and assemblies including head pulleys, drive pulleys, bend pulleys, take-up pulleys, power rollers and drive motor rollers. Most of these accidents could have been avoided by de-energizing of the belt and proper lockout and tag-out procedures.

Figure 11 shows the distribution of accident categories by year from 1995 to 2007. Except for 2003, the average number of fatalities per year reported was 4-5 accidents. The lowest number of accidents occurring per year was 3, and the highest was 8.

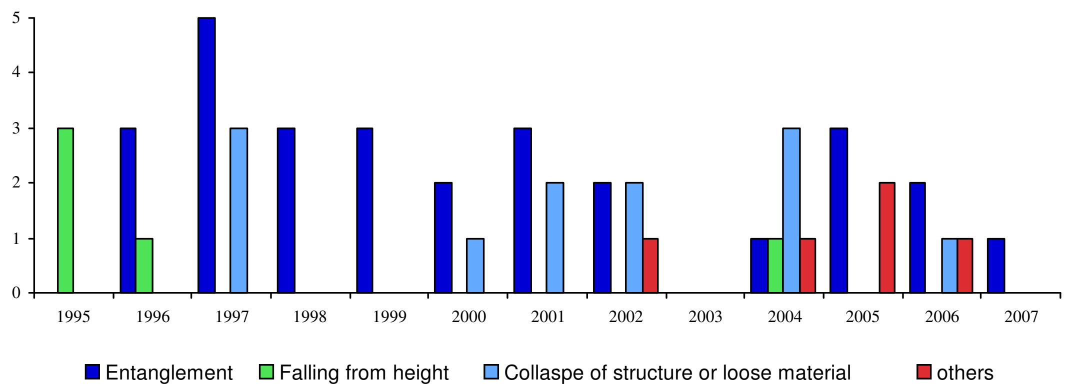

Figure 11: Distribution of belt-related fatal accidents by year

2.4 Training Requirements

Recognizing the need for conveyor safety standards during the 1940s, the American Society of Mechanical Engineers (ASME) issued safety standards through the American National Standards Institute (ANSI) for conveyors and related equipment (Schultz, 2003.). This was later modified to B20 in 1972 (a specification-based standard) and then to B20.1 in 1976 (a performance-based standard). The Occupational Safety and Health Administration within the United States Department of Labor (OSHA) was founded in the 1970's and started preparation of its own conveyor safety standards (20CFR, Part 1910.186). To date, OSHA has not adopted any conveyor safety standards and seldom become involved with conveyor safety inspections, which remain MSHA's responsibility. Because of the "chain of players" involved in the planning, engineering, manufacturing, installation, operation and maintenance of a conveyor or conveyor system, the responsibility for application of the safety standards is often misunderstood, ignored or simply overlooked.

Current training in the industry to understand conveyor belts and their safety is mainly the responsibility of the owner/operator of the mining facility. Both OSHA and ANSI classify conveyor belt safety into the general operational and safety training. They place the responsibility of training on the owner to use a certified, qualified and competent person to train the operators. Often times, this leads the owner of the mine to appoint a safety engineer. The common practices of training within the mining industry for conveyor belts are to incorporate the basic safety and awareness into videos and slide shows that are shown for required general safety training. With the lack of developed training programs, conveyor belt training is left to on the job training where a new employee is placed with experienced personnel to learn the workings of the conveyor belt and proper operations and maintenance. The one downfall for on the job training is that the training cannot be quantified and checked to make sure that the training period is adequate, it also allows for a chance of injury because inexperienced personnel are exposed to the dangers of a conveyor belt system (Shultz 2003).

According to Schultz (2003), conveyor safety operations and training are not adequately addressed by the ANSI standards or OSHA regulations. They place responsibility on the owner to limit job assignments to “certified,” “competent,” and “qualified” employees. When it comes to conveyor belt safety training, training materials as videos or text information is minimal as prepared by ANSI Conveyor Safety Standards, OSHA, or by any of the safety engineering professional associations. These associations have some general safety guidelines, but do not place requirements or suggest a training program structure or specific training guidelines (Schultz, 2002 and Schultz, 2003), leaving the responsibility of developing a successful training program to the owner/operator of belt conveyor.

2.5 Current Safety Training Requirements and Practices

In the United States, the Mine Safety and Health Administration (MSHA) is the governing entity for policies within the mining industry. As part of their Title 30 Code of Federal Regulations (CFR) Part 46, Section 46.3, each mining facility is to develop and implement a written training plan that includes programs for:

- New miners (§46.5)
- Newly hired experienced miners (§46.6)
- New tasks (§46.7)
- Annual refresher (§46.8)
- Site-specific hazard awareness training (§46.11)

- <u>New miners:</u>

  Section 46.5 requires new miners to complete at least 24 hours of training covering various topics listed in section 46.5 (b) & (c)
- <u>Newly hired experienced miners:</u>

  Newly hired experienced miner must receive newly-hired experienced miner training prior to beginning work at any different mine, training for any new tasks assigned, and at least 8 hours of annual refresher training every 12 months. If the experienced miner is an independent contractor, site-specific hazard awareness training is required at each mine. Also, the independent contractor must receive training for any new tasks and at least 8 hours of annual refresher training every 12 months.
- <u>New tasks training:</u>

  Training plans may list each task with corresponding teaching methods, training materials and evaluation procedures.
- <u>Annual refreshers training:</u>

Annual refresher's training program must address changes at the mine that could adversely affect the miner's health and safety.

• Site-specific hazard awareness training:

Part 46 allows for the flexibility to tailor hazard awareness training to the specific conditions and practices in mining industry. Also, Part 46 provides that site-specific hazard awareness training may be provided through the use of written hazard warnings, oral instruction, signs and posted warnings, walk around training, or other appropriate means that alert affected persons to site-specific hazards at the mine.

Section 46.5 requires new miners to complete at least 24 hours of training covering various topics listed in section 46.5 (b) & (c). As required in 30 CFR parts 46 and 48, only 4 hours of training must be given before the new employee starts work with the remaining twenty hours being performed within the first sixty days of work.

Newly hired experienced miners must receive training prior to beginning work at a different mine. This includes training for any new tasks assigned and at least 8 hours of annual refresher training every 12 months. If the experienced miner is an independent contractor that does work at multiple mines, they must receive site-specific hazard awareness training for each mine as well training for new tasks and the 8 hours of annual refresher training. The refresher courses that every miner takes must address changes at the mine that could adversely affect the miner's health and safety as well as regular safety practices. For new task training, the miner must complete a list of training materials and evaluations as recorded in the mines written training plan. Lastly, for site-specific hazard awareness training, 30 CFR Part 46 allows for flexibility to tailor hazard awareness training to the specific conditions and practices in the mining industry. Part 46 also provides that site-specific hazard awareness training may be provided through the use of written hazard warnings, oral instruction, signs and posted warnings, walk around training, or other appropriate means that alert affected persons to site-specific hazards at the mine (MSHA 2007).

Besides the requirements as listed by MSHA, some literature review and research was performed to determine what might be included in a training plan. Goldbeck (2003) proposed four categories of training areas for effective training programs, which include:

- General safety practices
- Guidance for performing maintenance and inspection
- Information about conveyor and belt conditions
- Procedures for belt tracking

General safety practices:

It include using the proper safety equipment, hardhats and glasses, to wear proper clothing and hair that is not loose or too long, and making sure that the each employee is aware of emergency stop button or cord locations.

Guidance for performing maintenance and inspections:

This includes making sure the conveyor is properly locked out and tagged out when performing maintenance tasks, performing maintenance tasks properly, and making sure any connected equipment is properly placed out of service and blocking, if necessary, is used.

Information about conveyor and belt conditions:
The employee also needs to be trained on belt conditions and be able to recognize impact and heat damage, belt cupping and cambering, or damage to belt splices. The training also needs to include general conveyor system conditions; such as to make sure idlers are properly working and having the ability to recognize spillage sources.
Procedures for belt tracking:
Lastly, Goldbeck explains belt tracking as a science of manipulating conveyor belt components to get the belt to run on the center of the structure. The improper adjustment of components when tracking the belt can lead to serious injury (Goldbeck, 2003).

Similar training program goals are described by Schultz (2003) who states that traditional safety hierarch priorities are eliminating the hazard or risk, applying safeguarding technology, using warning signs, training and instruction on a regular basis, and prescribing personal protection. Out of these safety priorities the training and instruction on a regular basis and the prescribing personal protection are the primary responsibility of the owner/operator. The training method that Schultz describes includes three steps. The first step is to set safety standards which include establishing performance standards for equipment, systems, personal, and operations and maintenance. It also includes that the design and manufacturing of the conveyor system has to perform to the safety standards when it comes to warning systems and safety factors. The second step is to set training requirements, meaning establish basic training procedures for all employees, and then developing procedures for training of new employees who are statistically involved in more accidents then the more experienced workers. The last step is to have management participation, periodic review, and continued training. This can be accomplished by keeping management involved and advised on all safety training programs and when they are scheduled, the use of monthly operational and maintenance safety review meetings, quarterly operations and maintenance conveyor belt safety review meetings to identify problems or changes which include identification and training of new equipment that can compromise safety and training part-time employees, and lastly keep a permanent record of all safety and health training that takes place by group or individual (Schultz, 2003).

One final location to check for safety training practices is the industry itself. Through interviews and site visits, three companies have been examined to see how they fulfill MSHA's requirements with their training techniques and how they go beyond those requirements with what they see as helpful. The findings of what the three companies participate in are shown in Table 1. The weekly meetings typically consisted of any new site-specific hazards that had arisen, or any specific maintenance work that the mine should be aware of. The rewards and incentive programs were two distinct programs. One company would have group outings that included picnics and social events after a successful inspection and other motivational rewards for periods of time without a reported incident. The other company used an individual and team monetary reward program. In this program, the individual was rewarded for his own safe practices by getting a set amount per quarter that he did not go without a written or verbal safety warning or incident. Additionally, each team member was awarded a second amount if their team did not have any verbal or written safety warnings or incidents. This helps to promote a safety environment by having each member of the team be liable and responsible for his or her team's actions. Finally, the informal safety talks would be about topics that seem to be lacking, about near misses that happened that week, or about fatalities and accidents at other facilities. These are typically about 15-30 minutes every week or two and happen in the field as a gathering or at the beginning of the day before the employees start their daily tasks.

Safety Training Practices	**Company 1**	**Company 2**	**Company 3**
MSHA Required Training (new employee & refresher)	√	√	√
Weekly safety meetings	√	√	√
Rewards/incentive programs	√	√	
Informal safety talks		√	

Table 1: Current industry training programs

Currently, most training that is taking place is within the MSHA guidelines for training and falls under general training, with very little of the training specifically directed at conveyor belts and conveyor belt safety. Within the industry, the training that focuses on conveyor belts and conveyor belt safety is usually conducted with slideshows and videos. This type of training is very passive and is hard to quantify the amount of knowledge that the employee is gaining through such training. The employees are often then placed with an experienced person for on the job training where they learn how to properly operate, repair, and maintain a conveyor belt system. If this training is incomplete it can lead to accidents that could have been prevented with a better training program.

2.6 Need for a Safety Training Program for Belt Conveyors

Recognizing the need for conveyor safety standards during the 1940s, the American Society of Mechanical Engineers (ASME) issued ANSI (American National Standards Institute) safety standards for conveyors and related equipment (Schultz, 2003.). This was later modified to B20 in 1972 (a specification-based standard) and then to B20.1 in 1976 (a performance-based standard). OSHA (Occupational Safety and Health Administration) was founded in the 1970's and started preparation of its own conveyor safety standards (20CFR, Part 1910.186). To date, OSHA has not adopted any conveyor safety standards.
According to Schultz (2003), conveyor safety operations and training are not adequately addressed by the ANSI standards or OSHA regulations. They place responsibility on the owner to limit job assignments to "certified," "competent," and "qualified" employees. When it comes to conveyor belt safety training, training materials as videos or text information is minimal as prepared by ANSI Conveyor Safety Standards, OSHA, or by any of the safety engineering professional associations. These associations have some general safety guidelines, but do not place requirements or suggest a training program structure or specific training guidelines (Schultz, 2002 and Schultz, 2003), leaving the

responsibility of developing a successful training program to the owner/operator of belt conveyor.

Since it is up to the operator of the conveyor belt system to structure their training programs, there are some essential elements that should be included. These essential elements include establishing learning objectives, preparing a course outline, allocating proper time, recognizing the level of training required (knowing who your audience is), documenting the training that take places, and evaluating the class/session effectiveness and making proper modifications (Shultz, 2003).

In order to help reduce accidents with a comprehensive safety-training program, it is important to include certain areas of training. Goldbeck (2003) proposed four categorizes of training areas: general safety practices, guidance for performing maintenance and inspection, information about conveyor and belt conditions, and procedures for belt tracking. General safety practices include using the proper safety equipment, hardhats and glasses, to wear proper clothing and hair that is not loose or too long, and making sure that the each employee is aware of emergency stop button or cord locations. Guidance for performing maintenance and inspections includes making sure the conveyor is properly locked out and tagged out when performing maintenance tasks, performing maintenance tasks properly, and making sure any connected equipment is properly placed out of service and blocking, if necessary, is used. The employee also needs to be trained on belt conditions and be able to recognize impact and heat damage, belt cupping and cambering, or damage to belt splices. The training also needs to include general conveyor system conditions; such as to make sure idlers are properly working and having the ability to recognize spillage sources. Lastly, Goldbeck explains belt tracking as a science of manipulating conveyor belt components to get the belt to run on the center of the structure. The improper adjustment of components when tracking the belt can lead to serious injury (Goldbeck, 2003).

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Currently, most training that is taking place is within the MSHA guidelines for training and falls under general training, with very little of the training specifically directed at conveyor belts and conveyor belt safety. Within the industry, the training that focuses on conveyor belts and conveyor belt safety is usually conducted with slideshows and videos. This type of training is very passive and is hard to quantify the amount of knowledge that the employee is gaining through such training. The employees are often then placed with an experienced person for on the job training where they learn how to properly operate, repair, and maintain a conveyor belt system. If this training is incomplete it can lead to accidents that could have been prevented with a better training program. Multi-media based interactive applications are being looked at as a solution to improve the current training practices of the industry.

2.7 Proposed Safety Training Structure

In order to have a successful and beneficial safety training program, it is important for it to be well thought out. Through this research and as depicted in Figure 12, a 4-step training program structure is proposed:

Step-1: Data Collection.

The first step of developing a safety-training program is collecting and compiling data and information. In the case of the research conducted, this was done through site visits and literature review. The next step in the process would be to determine the training areas.

Step-2: Identify Training Areas

As suggested above through the literature review this should include a comprehensives overview of safety issues and hazards and then maintenance and inspection. The categories as classified here are information about conveyors and belt conditions, safety issues, possible hazards, and maintenance procedures. When the categories are classified as they are here, it aids in the development and compilation of the information that is collected to make sure all areas are fully covered. Each of these categories is further sub-divided into information based upon their criticality and frequency of occurrence analyzed during the literature review and data collection phase. The information classified in this step forms the framework for the next step, which is the DSM prototype implementation.

Step-3: DSM Prototype Implementation

It is important to develop the program in stages that both inform the user and then test the user's ability to determine if the user is qualified under the training. The proposed DSM implementation is designed to provide non-linear interaction to explore information organized in the Digital Safety Manual. See chapter 5 for details of the DSM prototype implementation.

Step-4: Evaluation and feedback

It is also important to evaluate the developed program before implementation to make sure that the program is successful in reaching its goals of training the employee. See chapter 6 for details of the evaluation scheme.

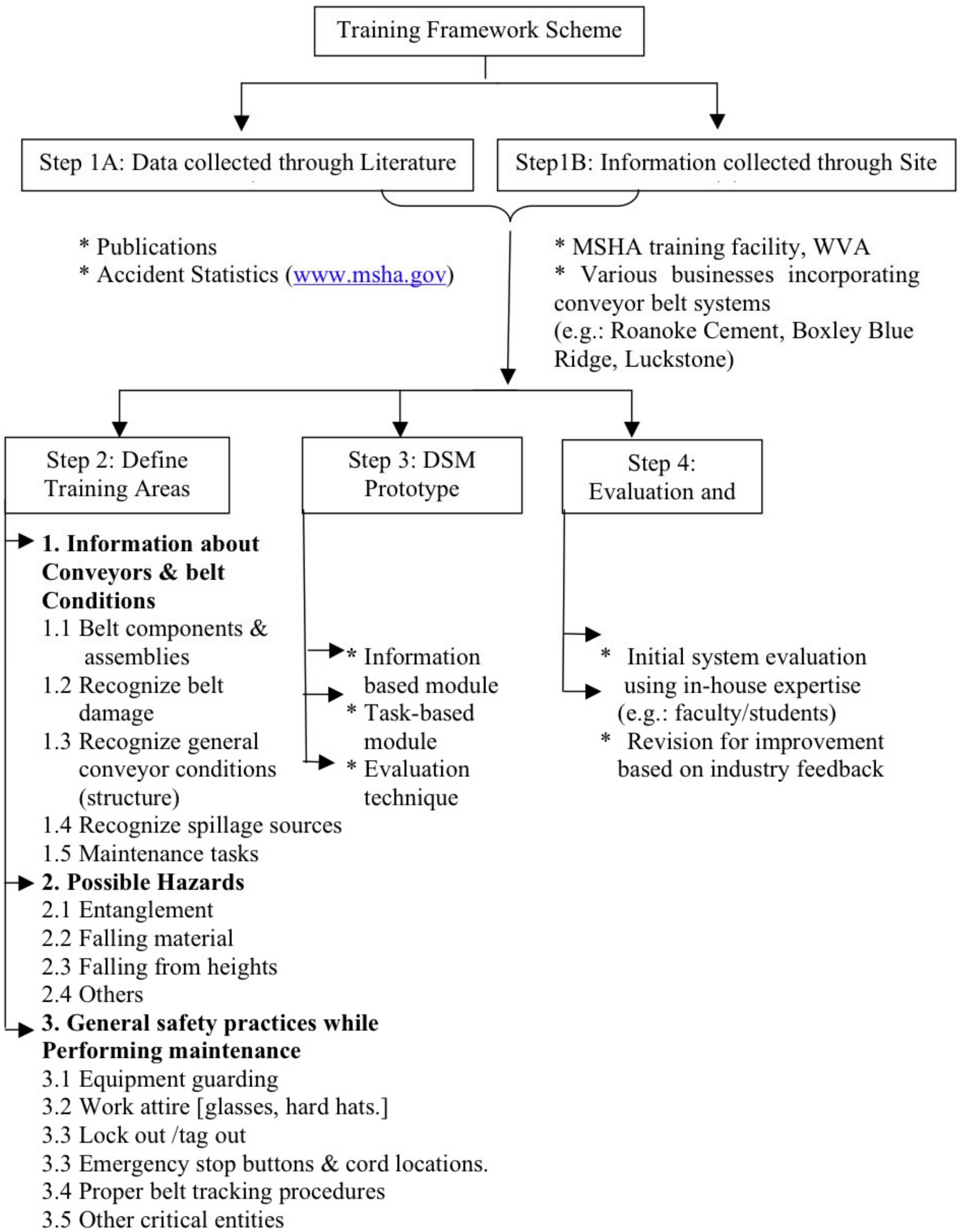


Figure 12: Proposed Safety Training Structure (Lucas, Thabet, & Worlikar 2008)

Chapter 3: Benefits of Multimedia-Based Learning Environments

The researchers believe that it is not simply enough for an operator to understand what needs to be done, but to justify why something is done in a certain way, and the safety, quality control and economic repercussions existing throughout the whole operation. Mining concepts are often complicated or remote; or systems are in operation and cannot be shut down for training purposes due to financial concerns such as lost time. The use of advanced media, such as videos or animations, combined with process simulations, allow the operator to examine a concept or practice in a new perspective and with no risk to him/herself, others, or property (Archibald, 1999). The need for flexible and continuous training for safety in an environment that is conducive to learning is becoming apparent for safe work place environments. Multimedia offers such environment, which provides flexibility and also allows for different medias to converge forming a unified outcome. Benefits of multimedia are as follows:

- Enhanced cognitive learning skills
- Learning by actively participating in the learning process
- Increased motivation
- Flexibility in terms of time and location

3.1 Enhanced Cognitive Learning Skills:

Cognitive learning is a process of acquiring knowledge and understanding through thought, experience, and the senses. The information that is acquired thorough cognitive learning undergoes a process known as cognitive information processing (CIP). Cognitive information processing is based on the thought process behind the behavior. The changes in the behavior are observed, but only as an indicator to what is going on in the learner's head. Cognitive information processing is used when the learner plays an active role in seeking ways to understand and process the information that he or she receives and relate it to what is already known and stored within memory. Cognitive information processing (CIP) seeks to explain how learning occurs in a multistore, multistage theory of memory (Driscoll, 1994). Implicit in this model is that information undergoes a series of transformations in the mind in a serial manner until it can be permanently stored in long-term memory in packets of knowledge that have a fixed structure. Following are the conditions under which cognitive information processing effectively contributes to learning:

- Learner has experience with subject matter or related area of knowledge.
- Resources are available to help the learner link the subject matter with existing knowledge.

- Learner needs or wants to be guided to a more developed understanding of the information.
- Instruction time is not severely limited.

Cognitive information processing relies on the existing knowledge of the learner and helps him/her to link new information to what he/she already knows. This could be proved, as drawback of cognitive information processing as learning may be distorted by what the learner already knows.

Cognitive learning is the integration of working memory and long-term memory. Working memory is the centre of cognition and scaffolds all the active thinking activities that occur (Clark & Mayer, 2003). Working memory (Baddeley & Hitch, 1974) deals with the consciousness of our everyday lives. Where as long-term memory is the final stop in the cognitive information-processing conduit wherein the information is permanently stored (Shiffrin & Atkinson, 1969).

3.2 Learning by Actively Participating in the Learning Process:

The focus of educating and training is shifting to learning by actually doing the task as apposed to just listening in the classroom based training sessions. Multimedia based learning is becoming the focus in various disciplines as this media is also based upon the cognitive learning experience. Cognitive theory of multimedia learning (Mayer and Moreno, 1997) outlines that learners have dual information processing channels of visual and verbal conduits to guide the educational development pathways. The auditory narration flows into the verbal system whereas animation is directed into the visual system. The researches have shown that the use of two different medias to convey the meaning is more effective than just text or just images. This precept advocates the use of words and pictures rather than words alone. Such a strategy facilitates learners to mentally build two schemas of understanding in the shape of a verbal model and a visual model and then construct connectivity and interactivity between the two to be able to integrate the new piece of information with the existing knowledge base (Mayer and Moreno, 1997).

When text and graphics are presented, they should be integrated and presented with corresponding words and pictures contiguously rather than separately. (Mayer and Moreno, 1997) by placing images along with the text it helps user to construct a coherent structure by visually drawing inferential connections between them. Non-linear nature of the multimedia-based learning allows the learner to explore and understand the subject without setting up a time restriction.

The standard passive methods of educating miners using mainly Power Point presentations in a classroom environment need to be revised to provide more pro-active methods of learning the subject matter. Research shows that less than 15% of the material covered in the classroom or corporate training room ever gets applied to the job (Broad and Newstrom 1992). The researches in cognitive science field have proven that by involving actively in the learning process enhances the process of acquiring knowledge and understanding through thought, experience, and the senses. Knowledge is derived from experience by way of the senses that produce in us simple ideas regarding the qualities of the objects that we perceive (England 1995).

Over the past few years methods of training has evolved from traditional classroom based training to computer-based interactive training. In traditional classroom based training the instructional information follows the strict structure developed by the training provider. Most of this information is updated time-to-time depending upon the advances/changes in the relative filed. The classroom-based training still remains one of the most desirable methods of training, as it is difficult to replace years of experience an instructor can impart during the training session. One of the concerns is how can the knowledge from experts can be captured and made it available for the future generations while taking into account the technological advances in training/education field. Computer-based training is one of the options that are being looked at as a solution to this. Such technology-based training is becoming more popular in educational, commercial and industrial sectors as it is believed to also enhance the cognitive learning of the user.

3.3 Increased Motivation:

One of the single most benefits of interactive multimedia as Marquardt (1999) describes is increased motivation. By virtue of involving more than one sensory mode and requiring user responses, interactive multimedia programs capture more attention and greater engagement on the part of worker/learners. Since getting a person's attention and keeping them interested is one of the most basic aspects of learning.

3.4 Flexibility in terms of Time and Location:

Another most important characteristic of the multi-media based programs is the kind of flexibility (in terms of time and location) they offer to the user. In traditional class room based training/instruction availability of the training provider and trainees need to be coordinated to schedule the training session but in computer-based training could be taken from either home or workplace as per their convenience. It also gives them the flexibility of taking their own time to comprehend the information in an environment that is conducive to learning. Presentation of the information also plays important role in the multi-media based training programs as these programs are self-directed and self-paced and consistent presentation of the information helps user from getting lost while exploring the program by making standardized presentation.

There are other benefits of developing an interactive multimedia-training program such as, comprehensive hub to house all the information scattered in various formats, updating and distributing the updates of digital information is comparatively more convenient as compared to the traditional methods. The extent of the multi-media training provided via CD-ROM or web based learning encompasses training that provides text, graphics, videos, animation, sound and interactivity in combinations previously unavailable by traditional training methods. The use of multi-media training offers extensions and in some instances replaces some of the most expensive or least effective segments of those traditional methods (Frankhauser 1996).

Multi-media interactivity is a programmed response to the user actions with the help of text, images, videos, animations and photographs. It gives users the flexibility to explore and navigate the training program at their own pace and by taking non-linear paths. Multi-media allow the hierarchical categorization of the information and gives flexibility to present the information in the most systematic and easy to understand manner in a collection of information. Different medias such as images, text, videos, animations, etc. converge together combining with interactivity to form one unified outcome. The use of multi-media in training programs is becoming more prevalent due to its effectiveness and cost efficiency. Frankhauser (1996) explains following reasons as to why use of multi-media is gaining popularity among the training program developers; costs, time saving, interaction, immediate feedback, consistency in presentation of the information, and flexible delivery.

Multi-media programs offer the opportunity to learn through non-linear exploration rather than tightly structured learning programs and also the researches have shown that the active learning/training is more effective when compared to the passive learning/training methods.

Chapter 4: Data Classification

4.1 Data Classification and Categories of the Digital Safety Manual

Based on the data collected during data collection process all the information is classified into four main areas which went on to become four categories of the Digital Safety Manual. Safety around conveyor belts involves understanding of three main components: 1] maintenance tasks to be performed on or around conveyor belts, 2] possible hazards associated with the maintenance tasks, and 3] safety measures that need to be followed to avoid these possible hazards. Our proposed research project addresses all these issues and equip user with the adequate knowledge about workings of the conveyor belt and its surroundings. The proposed Digital Safety Manual also serves as database for 50 fatalities discussed in the chapter 2 from 1995-2007 related to conveyor belts and incorporates statistics and detailed information about the accidents.

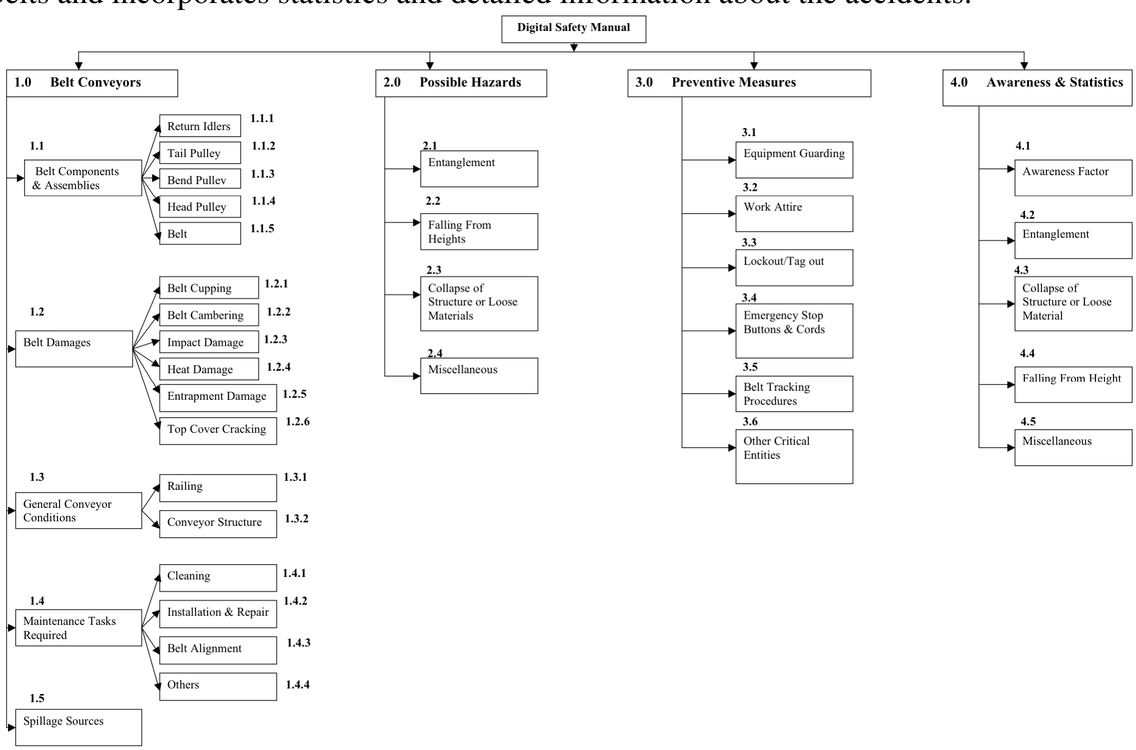


Figure 13: Flow diagram showing classification and categorization of the information presented in the Digital Safety Manual

Figure 13 shows classification and categorization of the information presented in the Digital Safety Manual. The four main categories of the DSM are Belt Conveyor, Possible Hazards, preventive Measures, and Awareness & Statistics. The detail of the information housed in each of the four major categories is as follows:

4.1.1 Belt Conveyors:

In order to fully understand the dangers of the conveyor belt and the need for training, it is felt that the reader be informed of the basic components of a conveyor system and where those injuries are most likely to occur. A belt conveyor has six basic components (see Figure 14), the belt, the belt support system (idlers), the pulleys, the drive, the structure, and the enclosure. Other parts can be added to these components in order to improve performance and decrease maintenance.

This category focuses on general information about conveyors and belt conditions and this category further divide into five sub-categories. These sub-categories are:

- 1.1 Belt components and assemblies such as return idlers, tail pulley, bend pulley, etc.
- 1.2 Recognize belt damages like belt cupping, belt cambering, impact and heat damage, entrapment damage, etc.
- 1.3 Recognize general conveyor conditions like broken railing or damaged conveyor structure
- 1.4 Maintenance tasks required such as cleaning, installation and repair, belt alignment, etc
- 1.5 Recognize spillage sources. This category is expected to give basic understanding of the knowledge about conveyors, its components and tasks that one might have to perform while working around conveyors.

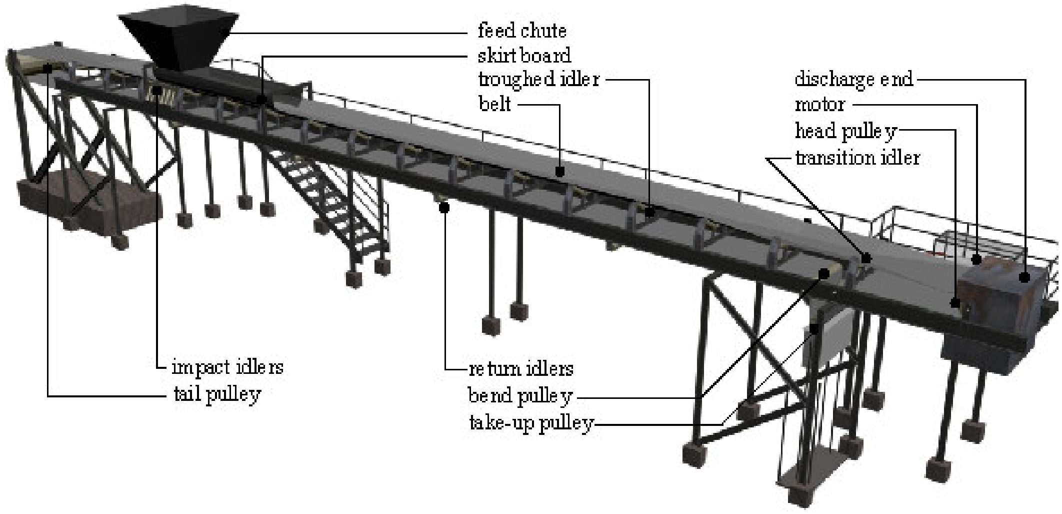


Figure 14: Conveyor belt components (Lucas, Thabet, & Worlikar 2007)

<u>*4.1.2 Possible Hazards*</u>

This category deals with the possible hazards related to conveyors like entanglement, falling from height, collapses of structure or loose material, and others. These sub categories are derived after analyzing 50 conveyors related accidents from 1995-2007 listed on msha website (www.msha.gov). These sub-categories are;

2.1 Entanglement
2.2 Falling from heights
2.3 Collapse of structure or loose material
2.4 Others

Within this category user will interact with above-mentioned four sub categories to learn more about them through digital images, videos, and general description about the individual hazard.

It is been observed that one of the most common hazards while performing maintenance tasks around belt conveyors is entanglement. Pinch points are the primary cause of the entanglement. Belt conveyors and their transfer points can be dangerous. By their very nature, they form many “pinch” points (Figure 2) and rapidly moving objects. These “pinch” points are the main cause for most of the accidents that happen around the moving conveyor belts. As the name suggests they form areas between the moving conveyor parts and belt where miners can get entangled or pulled during performing maintenance tasks

4.1.3 Preventive Measures:

This contains information about general safety practices while performing maintenance and further sub divides into seven sub categories. Intention of this category is to educate the user about safety measures that need to be taken while performing work around conveyors. These safety measures include:

3.1 Equipment guarding,
3.2 Proper work attire,
3.3 Lock out/tag out procedures,
3.4 Belt tracking procedures,
3.5 Emergency cord and stop buttons, etc.
3.6 Other critical entities

This category will help miner understand the importance of the practicing proper safety measures while performing work around conveyors.

The conveyor belt related safety practices are categorized as guarding, lock out/tag out, work attire and other critical entities like emergency cords along the belt, stop buttons at critical locations, start up alarm systems and railings. Guarding seems to be the most crucial safety factor with the conveyor belts and needs to be replaced before performing any maintenance task around the pinch points of the belt. While locking/tagging out the equipment is one of the most important safety precautions in mines. Lockout/Tag out is defined by MSHA as the “specific practices and procedures to safeguard employees from the unexpected energization or startup of machinery and equipment.” Lockout/Tag out procedure allows miners to perform maintenance tasks on the belt by putting lock and tag on energy isolating devices, which also informs other miners that task is being performed on the belt to avoid accidents. Third safety factor is wearing proper work attire while performing activities around the conveyor belt. Taking proper precautions can prevent these accidents and they need to be considered during construction, installation, maintenance, or inspection in the area of the belt.

4.1.4 Awareness & Statistics:

This category deals with the Case study analysis, which is basically statistical information, related to accidents occurred around conveyors from 1995-2007 also; it focuses on creating awareness among the miners. This category will give user access to all the 50 case studies, which we have analyzed and categorized into four categories such as:

4.1 Entanglement
4.2 Falling from height
4.3 Collapse of structure and loose materials
4.4 Others

Within this category user will learn about accident scenarios, statistics, and maintenance activities performed during the accident. This statistical information is collected from www.msha.gov.

Chapter 5: Research Methodology

The objective of this research was to develop a user friendly, "Digital Safety Manual" using multi-media technology and conducting evaluations and subjective analysis to measure the effectiveness and potential of the Digital Safety Manual concept. The Digital Safety Manual provides an interactive self-paced tool to inform the miners about the conveyor belt, conveyor belt components, and to alert the user of the safety issues and related hazards associated with the conveyor belt-working environment. It is our hypothesis that the proposed interactive multimedia-rich training/learning interface will allow for enhancing the cognitive learning process of users beyond traditional linear training programs eventually help in comprehending the knowledge during performing their daily tasks in the belt environment. The process of developing the proposed work was broken down into following four stages;

1. Data collection
2. Digital Safety Manual data classification
3. Digital Safety Manual concept and prototype development
4. Evaluations and Assessment of the developed prototype.

The first stage, which is Data collection, is explained in Chapter 2 and second stage, Digital Safety Manual data classification is explained in Chapter 3. This chapter, (Chapter 5) explains third stage, Digital Safety Manual concept and prototype development. The fourth and final stage is explained in Chapter 6.

This chapter is divided into the following two parts:

- Framework and concept of the Digital Safety Manual, and
- Prototype development and an example of Return Idlers.

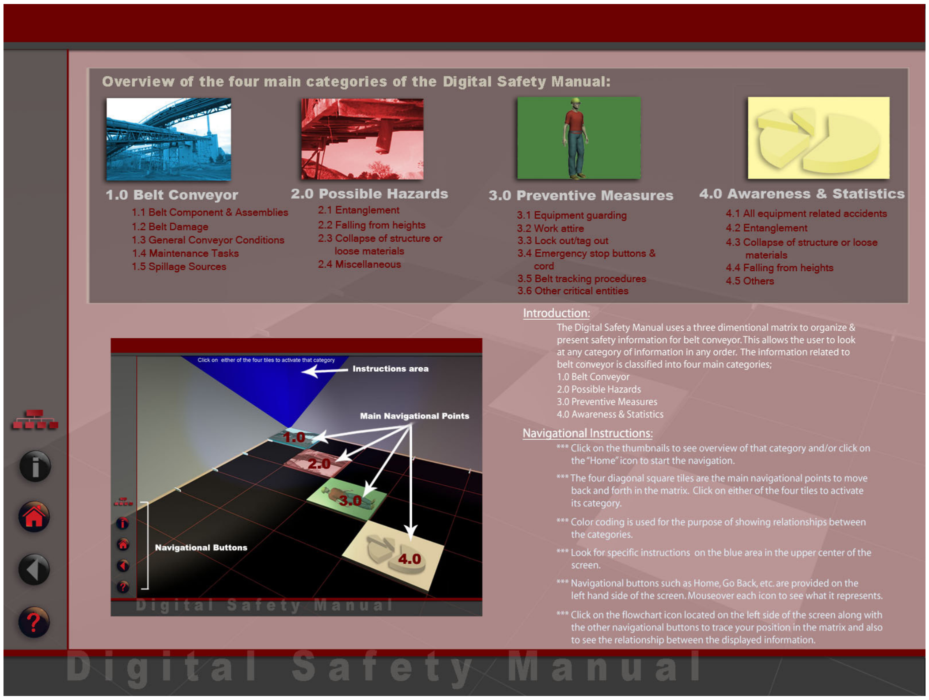
The first part explains the overall framework in which information is populated as well as the concept of the DSM. The second part describes the navigational path for the Return Idlers to explain the concept of the DSM.

5.1 Framework and Concept of the Digital Safety Manual

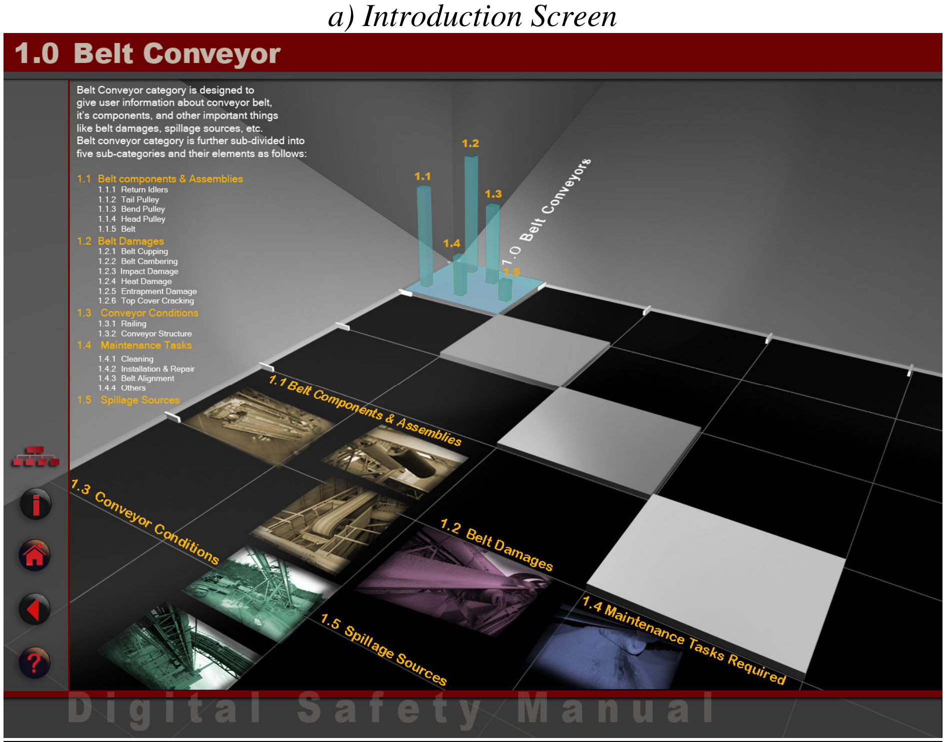
The framework for the Digital Safety Manual (DSM) uses a 3D matrix format to represent the four major information categories defined; belt conveyors, possible hazards, preventive measures, and awareness & statistics. The matrix allows development of the data categories and provides an effective/logical way to show relationships between the related information within these four categories. The framework for the manual allows for:

- Ensuring the effective organization and efficiency of navigation of the information
- Create user-friendly interface for maximum ease of information delivery
- To show the relationships between the information stored in different categories.

The DSM user interface in the prototype is designed in such a way that it provides the user an option of over viewing the four major categories before beginning the actual navigation of the DSM (see Figure 15). This is done to provide the user brief over view of what has been covered in each categories and also to set the tone of the 3D matrix presentation format.



a) Introduction Screen



b) An example of the "Belt Conveyor" category overview screen

Figure 15: Digital Safety Manual

The 3D matrix uses a 4 x 4 grid to display content and provide user the necessary navigational tools to explore the Digital Safety Manual. The DSM user interface has three features to correlate and display the information in the four main categories (see Figure 16).

1] The four diagonal square tiles on the surface of the 4x4 grid represent the domain location of four categories. They also, serve as main navigational nodes to switch back and forth between the categories.

2] The X coordinate of the diagonal square tiles displays the name of the activated category.

3] The Y coordinate of the diagonal square tile displays selected sub-category and other related categories to show the relationship between the selected sub-category and the information in other displayed categories.

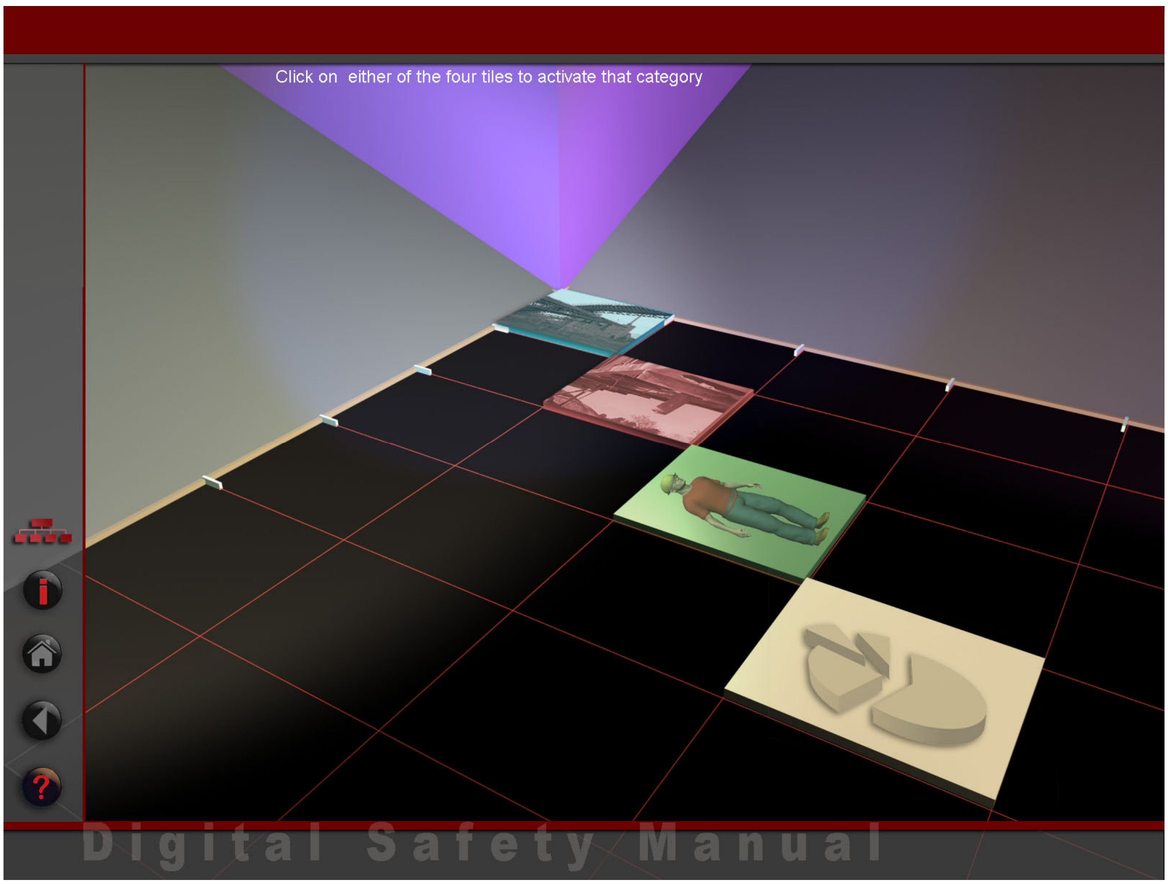
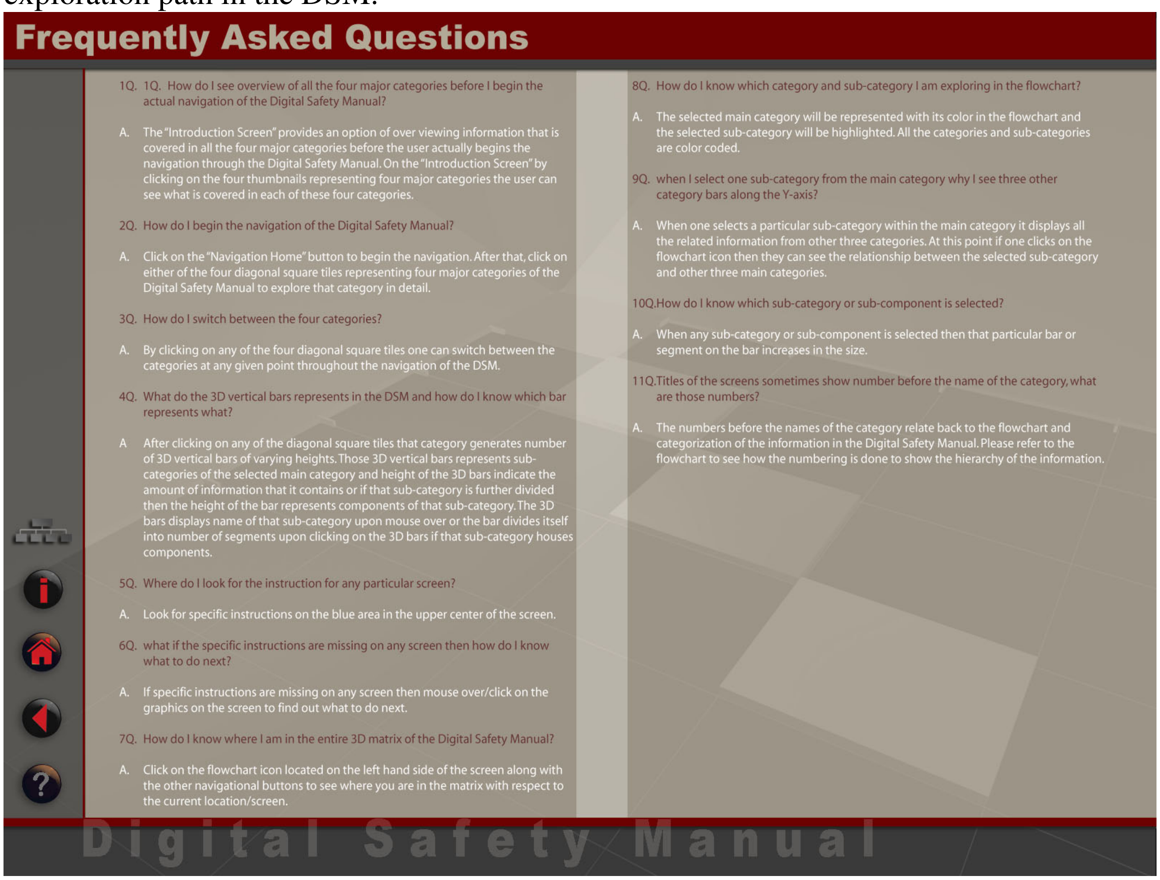


Figure 16: The DSM interface showing three features to correlate and display the information.

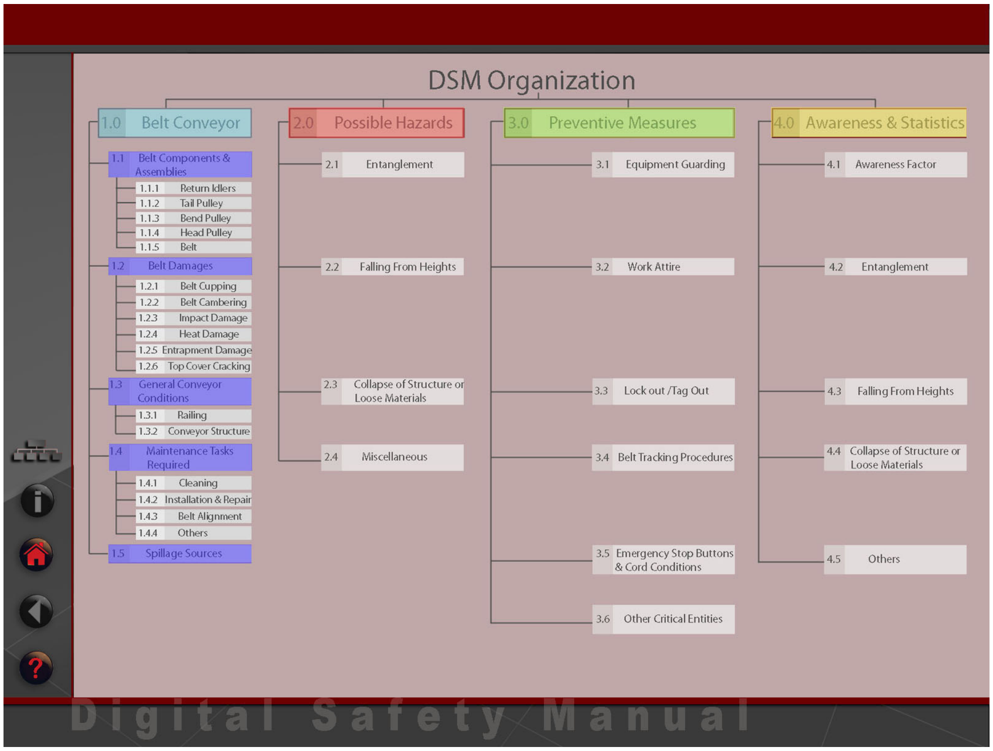
Upon activating any of these four square tiles by clicking on them will bring up the vertical 3D bars representing sub-categories within the selected category. The height or Z- axis of these bars symbolizes the amount of information that it contains. If there is further bifurcation within the sub-categories then the bar will be further divided into segments. Each category bars are color-coded to provide the visual link/grouping between the information when it appears at different points in time on the surface of the grid. The color-coding draws the link between the related information and helps the user to correlate the information that is presented with the same color square tile. This allows effective accessing and browsing the content in a collection. At any point the user will have an option and flexibility of selecting different category or sub-category for further exploration. This gives user the ability of non-linear navigation through the matrix. The information that is presented on the surface of the grid is the programmed response to the user's input and brings up a unique combination of information each time based on the selection. This combination demonstrates the related information in other categories pertaining to the selected sub-category. This is designed so that the user can trace the related information and can access all the information about the selected sub-category, which is scattered in the other three categories. To put it in simple words, the 3D matrix provides a tool to zoom on to one particular aspect/issue/component of the conveyor belt and highlights all the related information from the other three categories.

The user interface of the DSM also provides two navigational support tools in addition to the basic navigational tools to guide the user through out the navigation of the matrix. The first support tool provides the user navigational related help in the form of "Frequently Asked Questions" (see Figure 17a). It is designed so that the user can refer to the navigational instruction if and when needed during the exploration of the DSM. The second support tool traces the user's location on the color-coded hierarchical flowchart of the 3D matrix at a given point in the time (see Figure 17b). This tool is designed so that user can understand the relationship between the categories and map out his/her exploration path in the DSM.



a) Frequently Asked Questions screen in the DSM

Figure 17: Two informational navigation tools in the DSM



b) Flowchart tool in the DSM

Figure 17: Two informational navigation tools in the DSM

5.2 Prototype Development and Concept Demonstration

To demonstrate the concept of the 3D matrix and explore the capabilities of the DSM, one sub-category from the four main categories has been developed. See Figure 18 to see which sub-categories are developed in each of the four main categories.

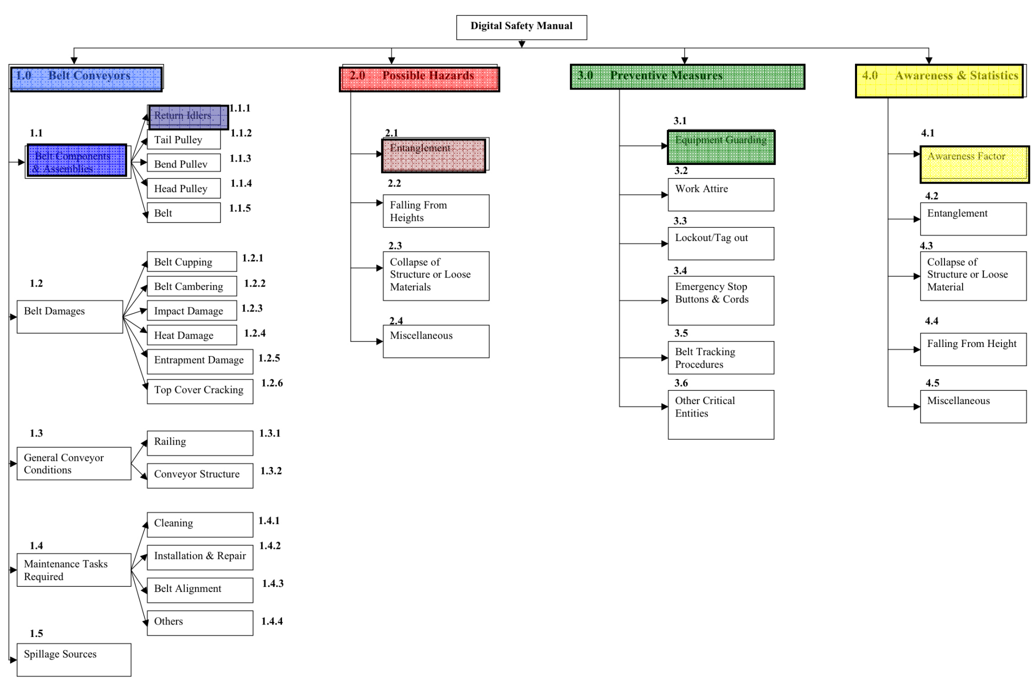


Figure18: Developed examples in the prototype of the DSM

An example of the *Return Idler* is described below to explain the 3D matrix concept. Once the belt conveyors category tile is selected (see Figure 19.2), the DSM displays 3D vertical bars representing the five sub-categories; belt components & assemblies, belt damages, general conveyor conditions, maintenance tasks required, and spillage sources. Here the height of the bars represents the number of components/areas under that sub-category. Upon clicking on these bars it divides itself into segments of information. In Figure 19.3, the user can mouse over each 3D vertical bar to review the name of the sub-category or can click and select a segment of the bar to further explore the information stored in that category. For example, when the user clicks on the *Belt Components & Assemblies* sub-category, the 3D bar divides into five segments namely, *Return Idlers, Tail Pulley, Bend Pulley, Head Pulley, & Belt.* By clicking on the *Return Idler* segment on the bar generates a combination of information from other three categories (possible hazards, preventive measures, & awareness & statistics) along Y-axis for the Return Idlers (see Figure 19.4). By clicking on each of these bars, the user can access the multimedia information associated with this component.

By clicking again on the Return Idler segment, the user can access related multimedia information (see Figure 19.4a). This provides the user general understanding of that component through digital images and videos. By clicking on the bar displayed on the *Possible Hazard* category tile, the user can explore hazards directly linked to the *Return Idlers* (see Figure 19.4b). This bar will provide information about the *Entanglement* hazard, which is most common with the *Return Idlers*. By clicking on the bars displayed on the *Preventive Measures* category tile, the user can learn about the recommended preventive measures that need to be considered when working around the moving *Return Idlers* (see Figure 19.4c). By clicking on the bar displayed on the Awareness & Statistics category tile, the user will be able to learn about the accident statistics and cause of the accidents that involved the Return Idlers (see Figure 19.4d). Also, this category is designed to give the user access to the actual fatalgram via URL link to the MSHA website. This category also emphasizes the awareness factor to initiate the safe work environment.

By following similar steps user will be able to explore and browse through the other three categories of the Digital Safety Manual. The 3D matrix provides an option of non-linear interactions to gain information about conveyors so at any point the user can switch between the four categories.

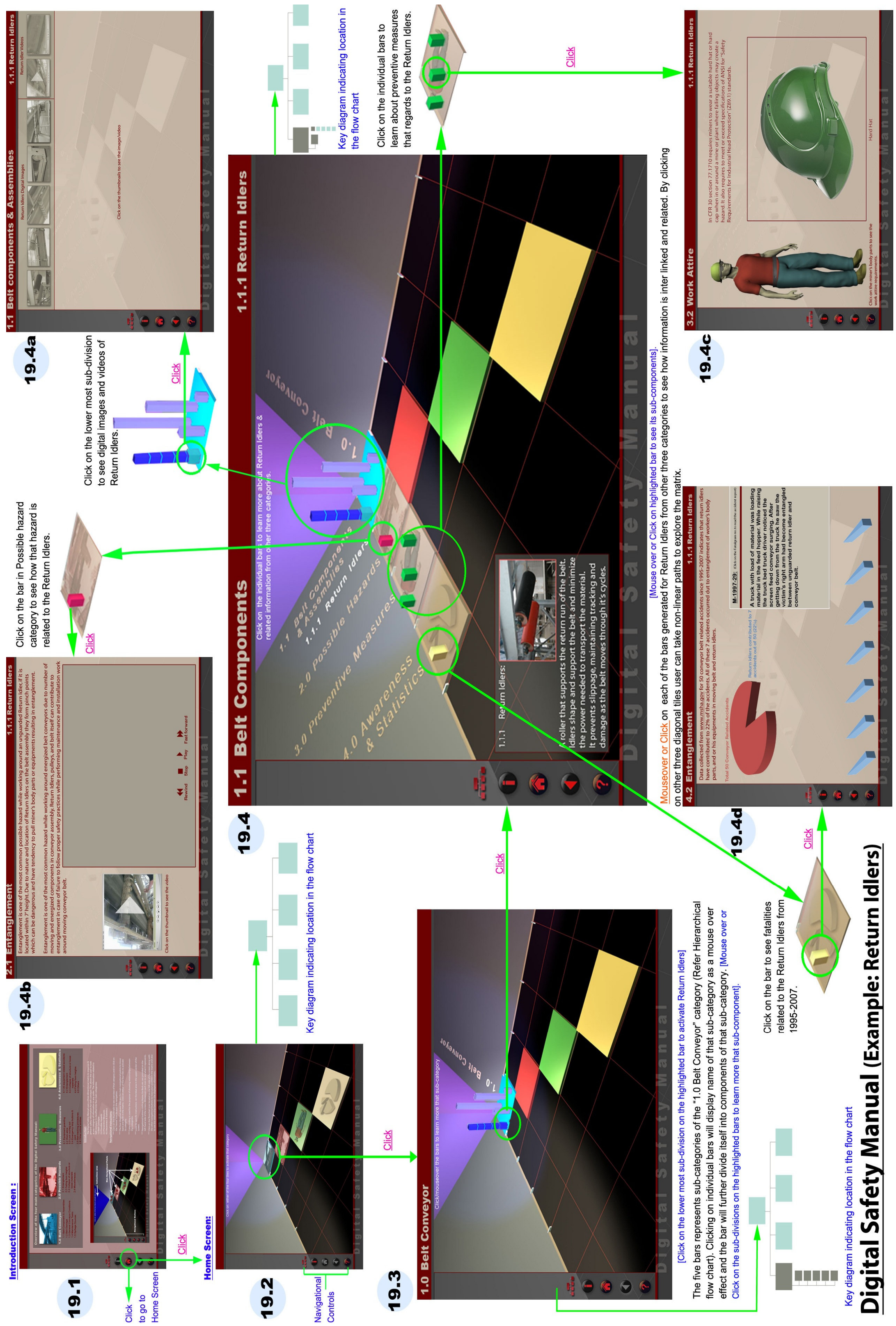


Figure 19: Digital Safety Manual, An Example of Return Idlers

Chapter 6: Evaluations & Results

It is important to make sure that the DSM responds to some of the industry's needs for learning and for its content, accuracy and consistency of the presentation. In order to accomplish this, the application was put through a series of feedback and usability evaluation pilot studies to measure the potential and applicability of this concept. Training evaluation is the systematic collection of data regarding the success of training programs (I.L. Goldstein 1986). Evaluation is conducted to answer either of the two questions: whether training objectives were achieved i.e. learning issues, and whether accomplishment of those objectives results in enhanced performance on the job i.e. transfer issues (Kraiger 1993). Even though both of these questions are equally critical and important, Campbell (1988) stressed that the most fundamental issue of evaluation is whether trainees have learned the material covered in the training. Shuell (1986) also argued that evaluation should be conducted first to determine whether the intended outcomes of training have been achieved. In recent times, dimension of technology seems prevalent in the developing training applications and hence the evaluation of such applications needs to take into account interaction, usability and aesthetics, and what influences user's preferences while developing evaluation methods. In computer-based training applications, evaluating user interface design plays a significant role, as interface of the application sets the users tone for the style of the interactivity that he/she is going to experience throughout the application.

For the purpose of evaluating outcome of the proposed research, pilot study of usability evaluations and subjective analysis were conducted through out the course of the development. The pilot test of usability evaluations is an evaluation of an unfinished user interface, done during each iterative design cycle, which aims to expose usability problems that exist in the current iteration.

The scope of this research work focused on doing the subjective analysis of comparison between the DSM and the typical training method as oppose to objective analysis. The reason for doing subjective analysis vs. an objective analysis was due to the fact that the DSM implementation is a prototype with limited information available to the user to explore. An objective analysis seeks to evaluate the application based upon relevant facts, regardless of the feelings where as the subjective analysis determines the outcome based on the feelings of the individuals taking part in the analysis process. An objective analysis would not have been relevant with the prototype of the DSM with the limited availability of the information.

Data Analysis

	Subjective (Opinion Based)	*Objective (Fact based)*
Qualitative	Usability Evaluations Involving both novice & Expert users to get	*Future Work*
Quantitative	Subjective analysis Involving both novice & Expert users to measure the potential Of the DSM concept As a learning tool	*Future Work*

Figure 20: Data analysis table

6.1 Framework of Evaluation Scheme & Process:

The pilot study of usability evaluation and feedback was both structured and unstructured involving industry professionals as well as non-industry personnel (novice users with no prior experience in the subject matter). Subjective analysis was user centered and helped in determining the potential of the DSM as a new learning approach where as usability evaluation was application centered and helped in determining accuracy and effectiveness, and consistency of presentation of the entire system.

The objective of the evaluation scheme was to:

1. Ensure that the information content are accurate, realistic, and consistent with industry training standards.
2. Improve the design of the graphical user interface (GUI), user friendliness, user control, and navigation.
3. Identify bugs and other programming problems.

The framework of evaluation scheme (Figure 6) was developed to guide the evaluation process. The evaluation scheme is divided into two phases: usability evaluations and subjective analysis.

Application evaluations helped us in validating the accuracy & relevance of the information that is incorporated in the DSM and it's interface related usability issues. Whereas the subjective comparative analysis helped us in qualitatively and quantitatively comparing the advantages of using the DSM versus traditional classroom based training methods qualitatively. The subjective comparative analysis was done to prove the concept of the DSM as oppose to measure the user's performance based assessment of knowledge retention. The scope of this research was to develop a prototype as a proof-of-concept as; the prototype cannot be used to analyze the user's performance due to its incompleteness.

The framework of evaluation scheme (see Figure 20) was divided into two major phases such as, usability evaluation and subjective analysis comparing the typical versus IT based training methods during which the application was updated to a new iteration based on the comments and reviews that we received. The first stage was focused on the usability evaluations and it was further sub-divided into two parts, industry feedback (for information review) and interface evaluations (see Figure 21). Industry feedback part of the application evaluation was unstructured and it was accomplished by conducting on site meetings with various industry professionals to gather their reviews on the information that is presented in the DSM for its accuracy and appropriateness. During this unstructured industry feedback session, industry professionals were given a demonstration of the applications and their comments were recorded and documented to revise the DSM prototype to its next iteration.

The new iteration of the Digital Safety Manual was then used for the second part of the application evaluation i.e. usability evaluations (see Figure 22). The usability evaluations were conducted by using two types of groups; group 1 was of novice users consisting of graduate students with various backgrounds who had no prior experience with conveyor belts or mining. Group 2 was consisted of industry experts or professionals who have experience with conveyor belts, mining, and are aware of conveyor belt environment. The reason for selecting such diverse groups for the interface evaluations was that it gave us a good measure of comparison between Gen X (technology savvy generation) with advanced technological expertise and no experience in the field of mining vs. experienced mining industry professionals with limited technological expertise. This evaluation helped us in evaluating efficiency and effectiveness of the DSM for future new miners.

6.2 <u>Demographics of the Participants:</u>

The evaluation scheme involved both novice and expert users. The industry expert users were used for three different purposes; to get review on the information presented, to get usability feedback on the DSM prototype, and for the subjective analysis to compare both the learning approaches. These experts were from three different mine operations in Virginia area. Demographics of both the groups of user are as follows:

<u>Novice Users:</u>

Both the phases of evaluation scheme involved total of 17 novice users. This group of participants' included both male and female users of age ranging from 22 to 40 years. Most of the novice users were graduate students (Master & PhD) from the Building Construction Department except three who were from various backgrounds such as, Computer Science, Psychology, and Architecture. All these participants are regular users of the Internet. Out of 11 participants 5 of them had prior experience using multi-media based interactive training applications before. Some of the examples of the applications used by the participants are; Small Business Development, Second Life Training, Red Cross Training, Software Training, Construction Industry Institute (CII) online learning course, etc.

<u>Expert Users:</u>

There were 12 industry experts involved in both the phases of the evaluation scheme. This group of industry experts involved professionals with various job backgrounds like, safety engineer, maintenance personnel, project manager, superintendent, safety manager, etc. with years of experience in the mining field. All of them are regular users of the Internet and most of them had prior experience of using multi-media based interactive training application such as MSHA's new miners safety training, driver training program, other safety training applications, etc.

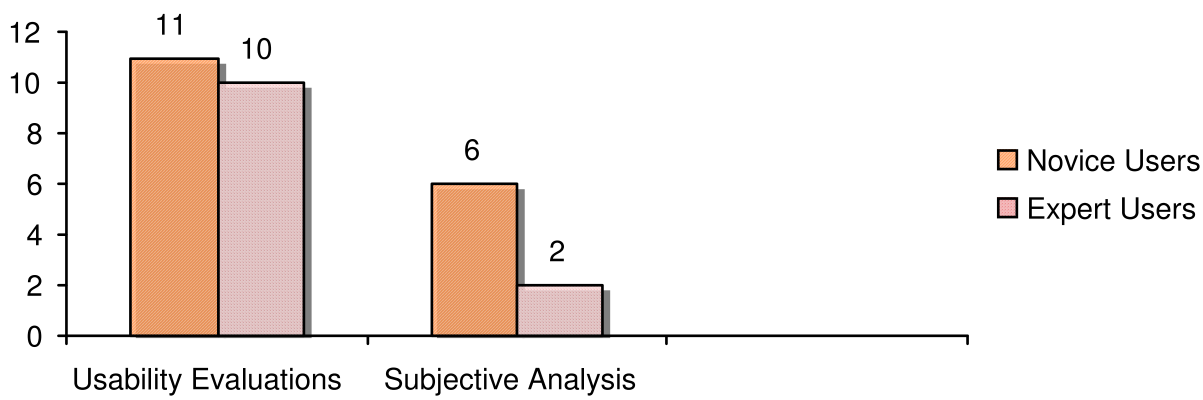


Figure 21: Bar chart showing different participants involved in the evaluation scheme.

The interface evaluation and qualitative comparison were the two very important stages of this master evaluation scheme as the outcome of these phases helped us to measure our objective of this research work. The interface evaluation part was designed to gather the user's feedback and comments on various issues. This research used a structured approach for interface evaluation by breaking down this process into two sessions. The interface evaluations were conducted with two test groups; group 1, of novice users consisting of mostly students with various backgrounds who had no prior experience with conveyor belts or mining, and group 2, industry experts or professionals who have experience with conveyor belts, mining, and are aware of conveyor belt environments (see Figure 22). By using two groups, a measure of comparison can be determined between a younger generation of users with no previous knowledge who are more likely to have technological experience and experiences mining professionals with subject experience and more limited technological expertise. This phase helped in determining the potential of this tool as a training approach.

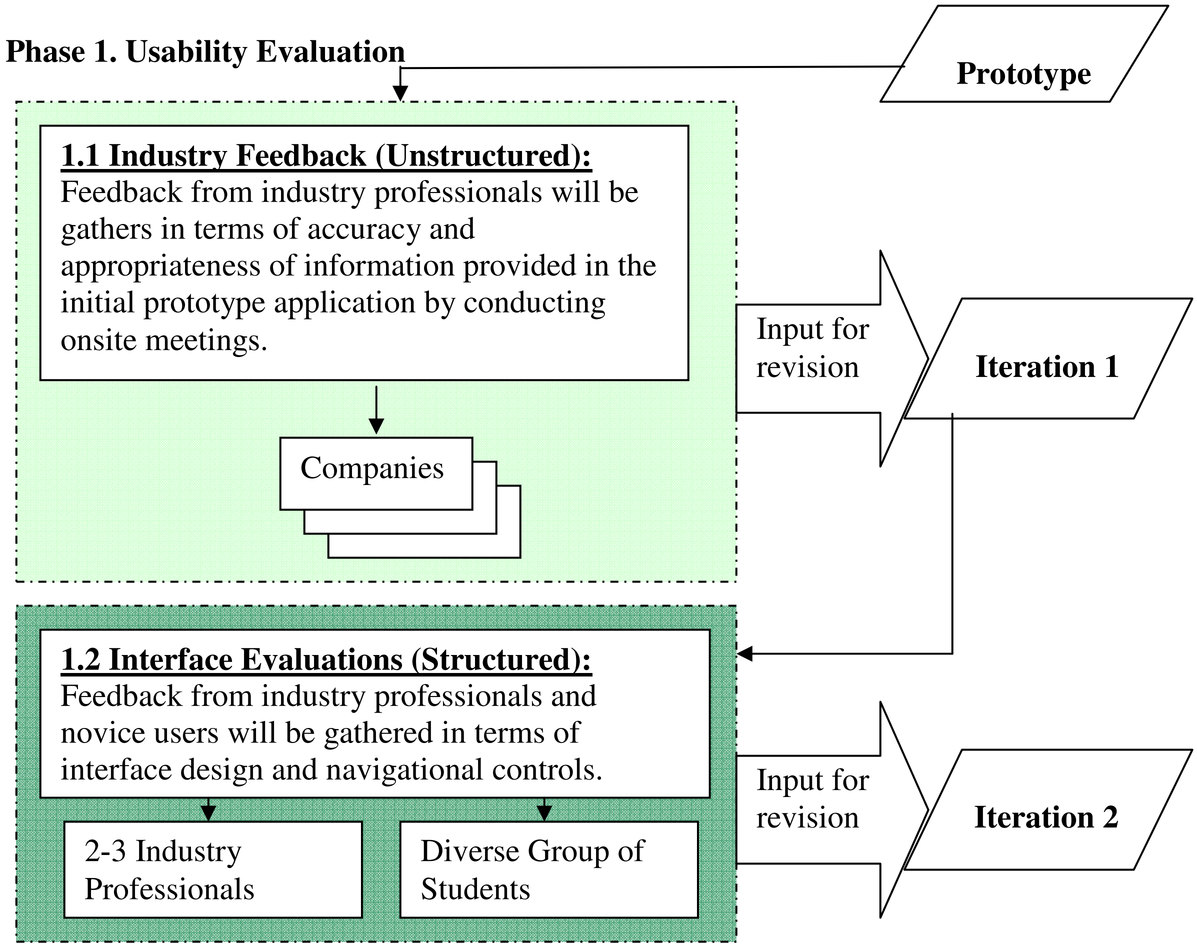


Figure 22: Details of first part of the evaluation scheme for the DSM i.e. Usability Evaluations

During the usability evaluations individual user from both the groups were first given introduction of the application, what they need to do and navigational instructions on how to maneuver through the application. After that they were give 20-30 minutes to explore the prototype application by themselves. The users of both the groups were then asked to complete a similar evaluation questionnaire where each participant rated their agreement with statements dealing with clarity of instructions, navigation of each application, and presentation of the information. Once the findings of the questionnaires were looked at, it helped in determining what aspects of the applications needed the most improvement, this process was repeated with each of the user to gather usability evaluations to develop the next iteration for the final part of master evaluation scheme i.e. the subjective analysis to compare the typical versus IT based training applications.

Data was collected, reviewed, and findings synthesized from the usability evaluations, it was used to develop the new (final) iteration of the DSM. This new (final) iteration of the DSM was then used in a subjective analysis to compare the learning advantages in IT based training applications vs. in typical classroom based training methods. This analysis was the most critical and important part of this research, as this validated the potential of such training application depending on the results that were received after the subjective analysis. At this stage of the evaluation scheme two groups were used, one group consisted of novice users with no prior experience and second group consisted of industry experts (see Figure 23). The first group was first given a paper manual, binders, and loose photographs, videos that would be typically found in the industry as training delivery material, and then we simulated the classroom based training delivery method using the information that was gathered during data collection stage. After presenting training information in classroom based structured format, the same group received demonstration of the revised DSM presenting the similar information in non-linear interactive environment for the same amount of time. After simulating both the training methods each group were asked to complete the qualitative comparison survey (see Appendix D). The industry experts were only given demonstration of the prototype application, as they are aware of traditional training methods currently used in the industry. The findings of which was documented (see Section 6.3).

Phase 2. Subjective Analysis

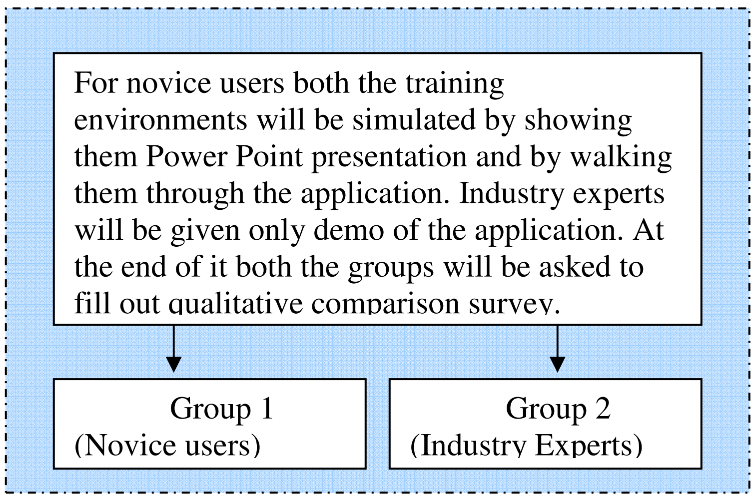


Figure 23: Details of part 2 of the evaluation scheme for the DSM i.e. Subjective Analysis

This entire process helped in determining the stated objective of this research project, use of interactive multimedia to increase the cognitive skills of the user by self-paced learning. At the end of the evaluation process all the findings were documented based on the feedback and evaluations gathered from the industry experts and novice users.

6.3 Evaluation Results:

6.3.1 Results of Usability Evaluations: (Novice Users)

The findings received from the novice users are categorized into three groups; navigational issues, design layout issues, and general issues (see Table 2).

Q. No.	Issues	Number of participants commented			
		Disagree	Agree	Strongly Agree	N/A
	Navigational Issues:				
Q. 1	Clarity of navigational instructions	0	6	3	2
Q. 2	Ease of navigation	1	6	5	1
	Design/layout Issues:				
Q.3	Overall design/layout of the GUI	1	5	5	1
Q.4	Consistency and readability of the text size and color	0	4	7	0
Q.5	Understandability of the information	0	7	6	0
Q.6	Ease of understanding relationship between the categories of information	0	8	0	3
Q.7	Color-coding	1	5	4	2
Q.8	Ease of understanding the height of bars representing the amount of information	0	6	3	2
Q.9	Use of multi-media (Videos, pictures, text, etc.) is effective	0	4	7	1
Q.10	Incorporation of the information framework flowchart is effective	0	4	6	2
	General Issues:				
Q.11	Overall experience using the DSM as a learning tool	0	4	6	0

Q.12 Top most liked things about the DSM

- Engaging experience and very intuitive way to navigate
- Unique design
- Use of multi-media objects and interactivity
- Use of color-coding to draw link between the categories of information
- Overall organization and good use of information framework flowchart

Q.13 The least liked things about the DSM

- Not everything is developed
- Navigational bugs
- Some amount of learning curve to get used to the DSM

Q.14 Applicability of the DSM concept in the Construction Industry (10)

- Safety manuals, building codes, employee manual, innovative commercialization matrices, company resource manuals, etc.

Q.15 General comments & suggestions

- Add mouse over label on the bars
- Provide short description for images
- Add voiceover narration of the text
- Change location of the navigational button

Table 2: Novice Participant's comments on the various topics covered in the Usability Evaluations Questionnaire

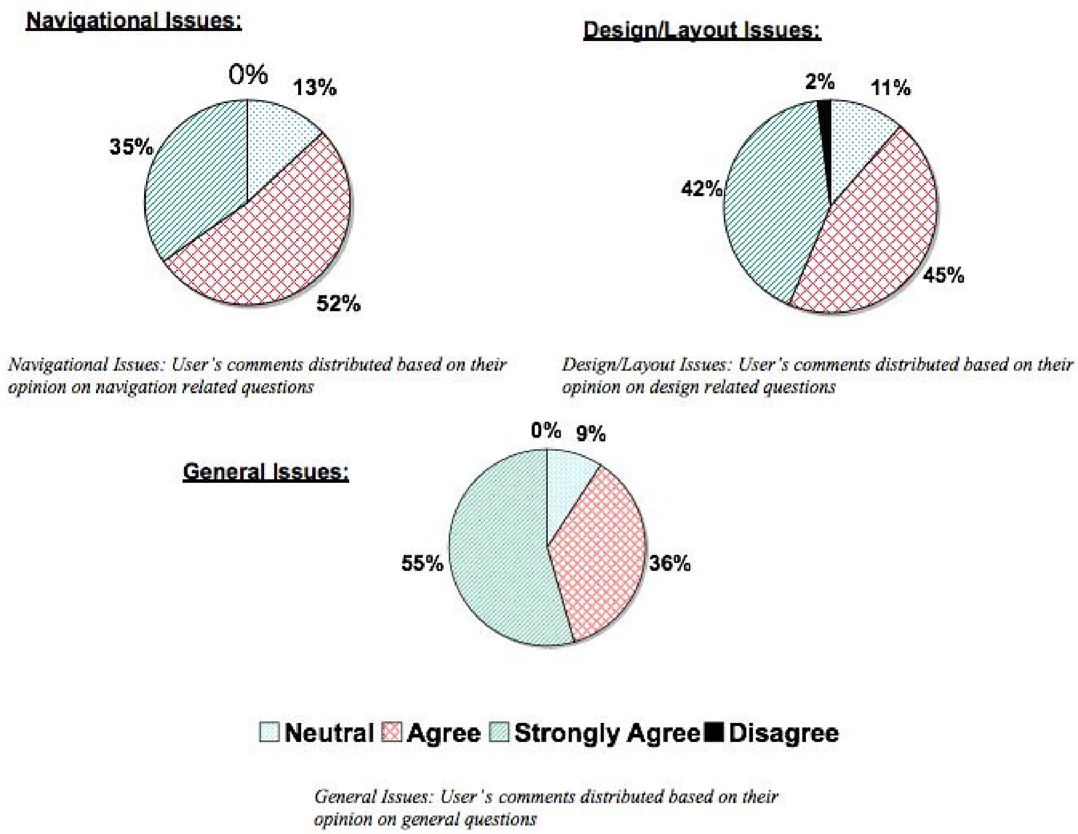


Figure 24: Percentage distribution of the user's comments on the three main areas of the Novice Users Usability Evaluation Questionnaire

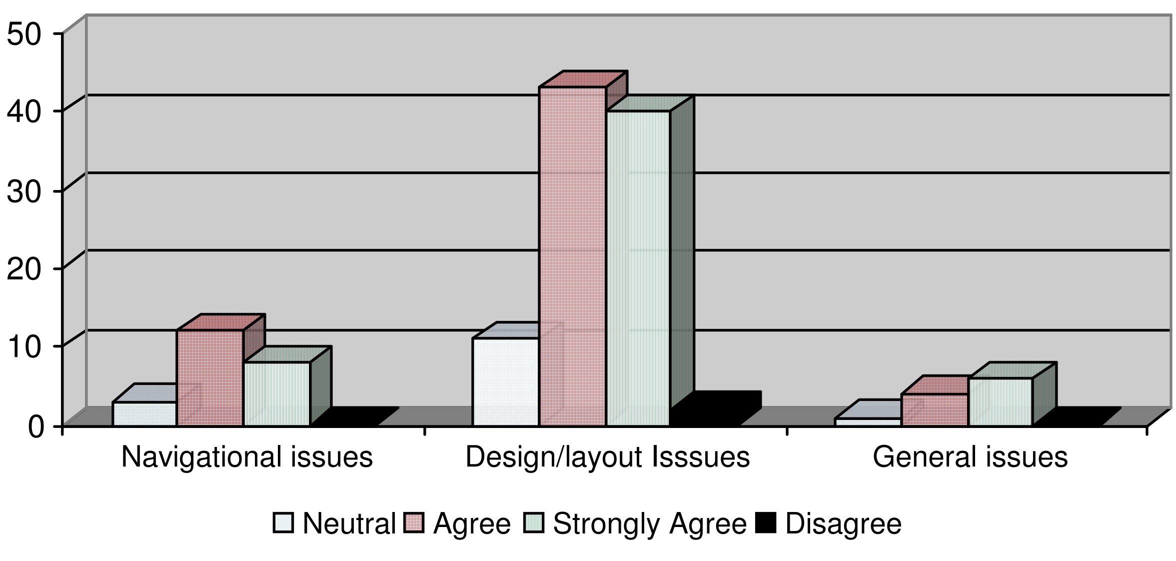


Figure 25:Novice User's Usability Evaluations results: Comparison between number of comments received in each of the three main areas

The findings that were received after novice users usability evaluations were analyzed and documented as shown in Table 2 and Figure 24 & 25. Feedback on the navigational issues was largely positive. 52% of the participants agreed that navigation is simple and easy to get used to and navigational instructions were easy to understand. 35% strongly agreed to these statements while 13% of the opinion from the participants was neutral. None of the participants expressed their disagreement with the navigational statements. Findings from the design/layout evaluation show that the results were largely positive with a very small portion of disagreements. Out of the total number of participants 45% of the participants agreed that the overall of design layout and user interface related things met their expectations. 42% of the participants showed strong agreement with the design/layout statements. There are almost equal amount of participants expressed their agreement and strong agreement. Around 11% of the participants were neutral about their opinion and 2% were disagreed with the statements from the design/layout issues.

The last section of the usability questionnaire asked general questions like overall organization of the DSM is effective, and the DSM exploration is an interesting and engaging experience. It also asked general questions like the most liked and least liked things about the DSM, applicability of the DSM concept in the construction industry, and general comments. Some of the more desirable aspects of the DSM are engaging experience and intuitive navigation, unique design, use of multi-media objects & interactivity, overall organization, etc. Some of the least liked things about the DSM are navigational bugs, the amount of learning curve, and not all the things are developed.

When asked about the applicability of the DSM concept in the construction industry, the participants responded by saying it definitely has potential and could be used as safety manuals, building codes, company resource manual, innovation commercialization matrices, etc. Along with these suggestions some of the general comments included adding a label on the bars, short description for the images, add voiceover narration, etc.

Results of Usability Evaluations: (Expert Users)

Similarly, the findings received from the expert users are categorized into three groups; navigational issues, design layout issues, and general issues (see Table 3).

Q. No.	Issues	Number of participants commented			
		Disagree	**Agree**	**Strongly Agree**	**N/A**
	Navigational Issues:				
Q. 1	Clarity of navigational instructions	1	1	0	0
Q. 2	Ease of navigation	1	0	0	1
	Design/layout Issues:				
Q.3	Overall design/layout of the GUI	1	1	0	0
Q.4	Consistency and readability of the text size and color	0	2	0	0
Q.5	Understandability of the information	2	0	0	0
Q.6	Ease of understanding relationship between the categories of information	1	0	0	1
Q.7	Color-coding	1	1	0	0
Q.8	Ease of understanding the height of bars representing the amount of information	0	2	0	0
Q.9	Use of multi-media (Videos, pictures, text, etc.) is effective	0	0	2	0
Q.10	Incorporation of the information framework flowchart is effective	1	0	0	1
	General Issues:				
Q.11	Overall experience using the DSM as a learning tool	0	2	0	0

Q.12 Top most liked things about the DSM

- Good way to present information
- Use of videos and pictures
- Great tool fro training

Q.13 The least liked things about the DSM

- Needs to be more user-friendly
- Needs labels and better color-coding
- No tracking system to keep record of user performance
- No definite structure

Q.14 Applicability of the DSM concept in the Construction Industry (10)

- Safety manuals

Q.15 General comments & suggestions

- Add mouse over label on the bars
- Make it more user-friendly

Table 3: Expert Participant's comments on the various topics covered in the Usability Evaluations Questionnaire

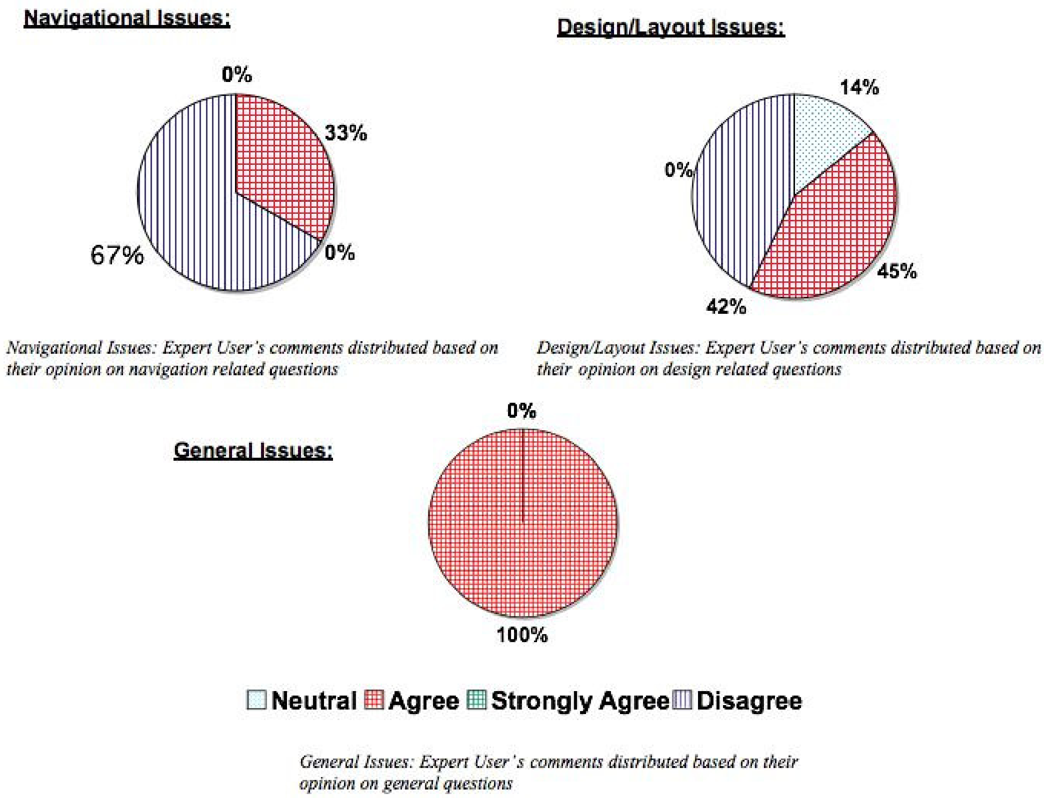


Figure 26: Percentage distribution of the user's comments on the three main areas of the Expert Users Usability Evaluation Questionnaire

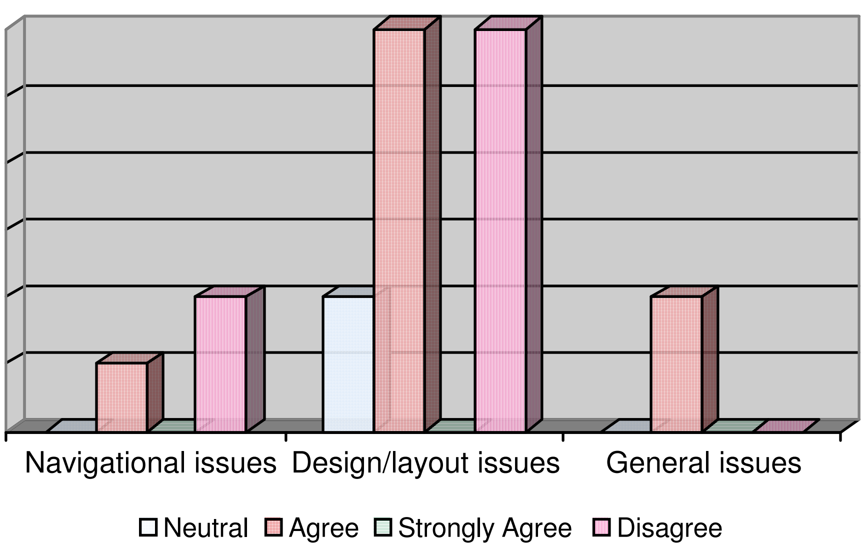


Figure 27:Expert User's Usability Evaluations results: Comparison between number of comments received in each of the three main areas

The findings that were received after expert users usability evaluations were analyzed and documented as shown in Table 3 and Figure 26 & 27. Feedback on the navigational issues was comparatively negative. 67% of the comments on the navigational issues were in disagreement while 33% of the comments were in positive. In design/layout area there were almost equal amount of comments that were in agreement and disagreement. 45% were in tune with the statements that were posed in this section while 42% disagreed.

The last section of the usability questionnaire asked general questions like overall organization of the DSM is effective, and the DSM exploration is an interesting and engaging experience. It also asked general questions like the most liked and least liked things about the DSM, applicability of the DSM concept in the construction industry, and general comments. Some of the most liked things about the DSM are good way to present information, use of videos and pictures, and a great learning tool. Some of the least liked things about the DSM according to the industry experts are, less user-friendly, no tracking system record user performance, no definite structure, etc

When asked about the applicability of the DSM concept in the construction industry, the participants responded by saying it definitely has potential and could be used as safety manuals, company resource manual, etc. Along with these suggestions some of the general comments included adding a label on the bars, user-friendlier, etc.

Expert users were also asked questions on the information presented in the DSM. There were few suggestions given on the information presented such as; inclusion of CFR codes and MSHA standards in the textual information that was presented. All these comments were documented and then implemented during the next iteration of the DSM prototype.

All these comments were analyzed and used to develop the next iteration of the DSM prototype. Also, this helped in identifying future areas of improvement based on the comments and suggestions received. These future areas are discussed in the discussion chapter in greater detail. Some of the suggestions are as follows:

- Develop the DSM in its entirety
- Conduct proper usability studies of the fully developed application
- Add some sort of tracking system to record user's performance
- Incorporate find/search commend in the DSM and make it more dynamic.

6.3.2 Results of Subjective Analysis:

Results of Novice Users subjective analysis:

Q. No.	Question	Answers	No. Of People Commented
Q.1	Advantages of typical training	Questions & doubts can be solved immediately	3
		One-on-one interaction/physical presence	5
		Years of experience of an instructor	2
		Conducive environment for learning from others	3
Q.2	Advantages of the DSM	Increased motivation	3
		More learnability	3
		Better retention of the information	2
		Interactive and engaging experience	4
		Ease of accessibility	3
		Flexibility in terms of non-linear interactivity	4
		Good reference source	2
		Easy to update	1
Q.3	Beneficial features of the DSM	Use of videos & pictures along with the text reinforces the understanding of the subject matter	5
		Non-linear interaction	4
		Learnability and interactivity	4
		Good way to show relationship between the information	2
Q.4	Shortcomings of the DSM	No tracking system to record user performance	2
		Some level of learning curve in the beginning of the exploration	2
Q.5	Is the DSM an effective way of learning? Why?	If fully developed, potential of increasing retention of the information	2
		Can be used as supplementary training method along with the typical training method	3
		Increased motivation and more actively involved due to interactivity	5
Q.6	Which training method is more effective?	The DSM due to interactivity, non-linear exploration, engaging, flexibility to add & explore, better knowledge retention ability, easy to update.	4
		Since the DSM is a prototype so at this time typical method is better because all the information is available unlike in the prototype application of the DSM	2

Table 4:Novie User's comments on the various topics covered in Qualitative Comparison Survey

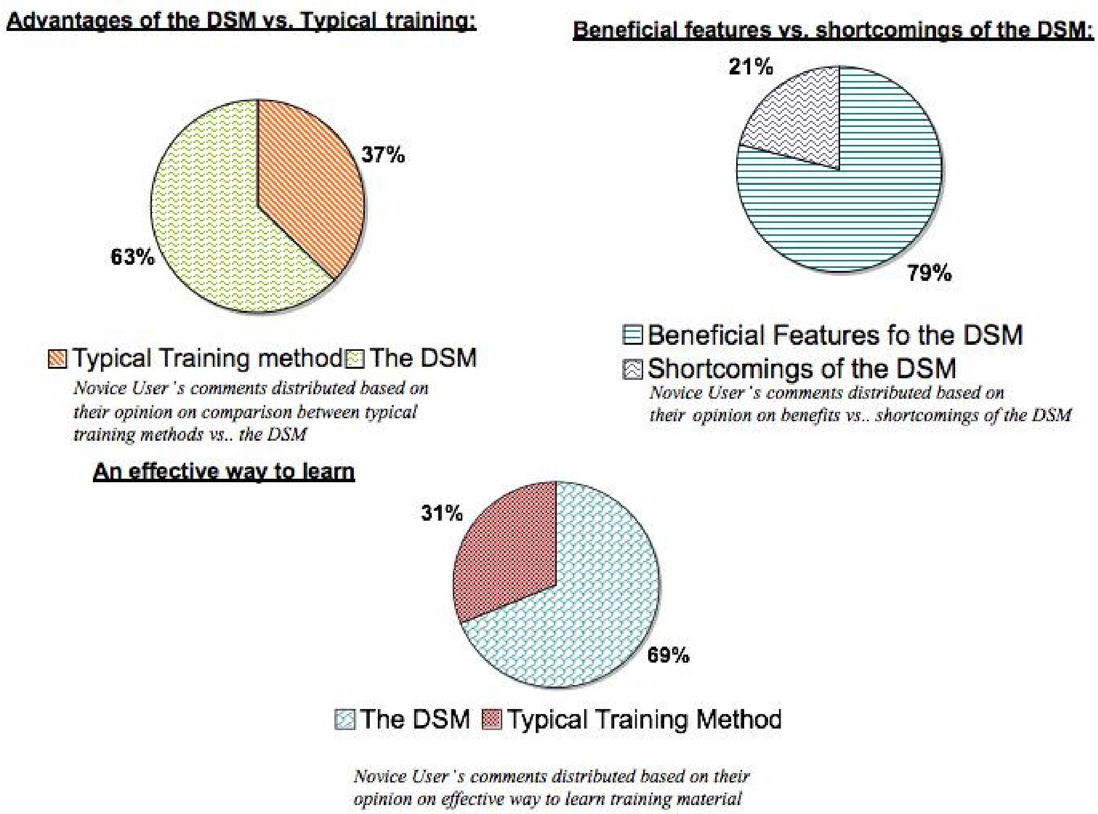


Figure 28: Percentage distribution of the Novice user's comments on Qualitative Comparison Survey

The findings that were received after novice users qualitative comparison between two learning approaches were analyzed and documented as shown in Table 4 and Figure 28. Feedback on the qualitative comparison was largely positive. 63% of the comments received from the novice participants said that the DSM has more advantages over the traditional training method where as only 37% commented that the typical training method has more advantages. These 37% participants main concern was that the DSM is not fully implemented and not all the information is available to explore but when it's developed completely it will be more advantageous as compared to the typical training method.

About the beneficial features of the DSM 79% of the participants commented that there are more benefits in learning by using the DSM while rest of the 21% commented that there are few shortcomings of the DSM. Their main concern was that the years of experience an instructor has could not be replaced by the computer-based applications. On the similar lines, 69% of the participants said the DSM is an effective way to learn training material if implemented fully where as 31% said that even though the DSM has many advantages it can be used as a supplementary training material along with the typical training method.

Results of Expert Users subjective analysis:

The findings received from the industry experts are as follows (see Table 5).

Q. No.	Question	Answers	No. Of People Commented
Q.1	Advantages of typical training	More structured approach	1
		Questions can be asked during the training and typical method is relatively easy to understand	1
Q.2	Advantages of the DSM	No need of instructor	1
		Interactive and engaging experience	1
		Possibility of incorporating unlimited information	1
		Easy to update	1
Q.3	Beneficial features of the DSM	Use of videos & pictures along with the text reinforces the understanding of the subject matter and interactivity	1
		Access to statistical information	1
Q.4	Shortcomings of the DSM	No tracking system to record user performance and need more structure	1
		Some level of learning curve in the beginning of the exploration	1
Q.5	Is the DSM an effective way of learning? Why?	If fully developed, potential of increasing retention of the information due to use of videos, pictures, etc.	1
		Can be used with typical training methods	1
Q.6	Which training method is more effective?	The DSM due to interactivity, non-linear exploration, engaging, flexibility to add & explore, better knowledge retention ability, easy to update.	2
		Knowledge can be acquired at own pace	1

Table 5: Industry Expert's comments on the topics covered in the Qualitative Comparison Survey

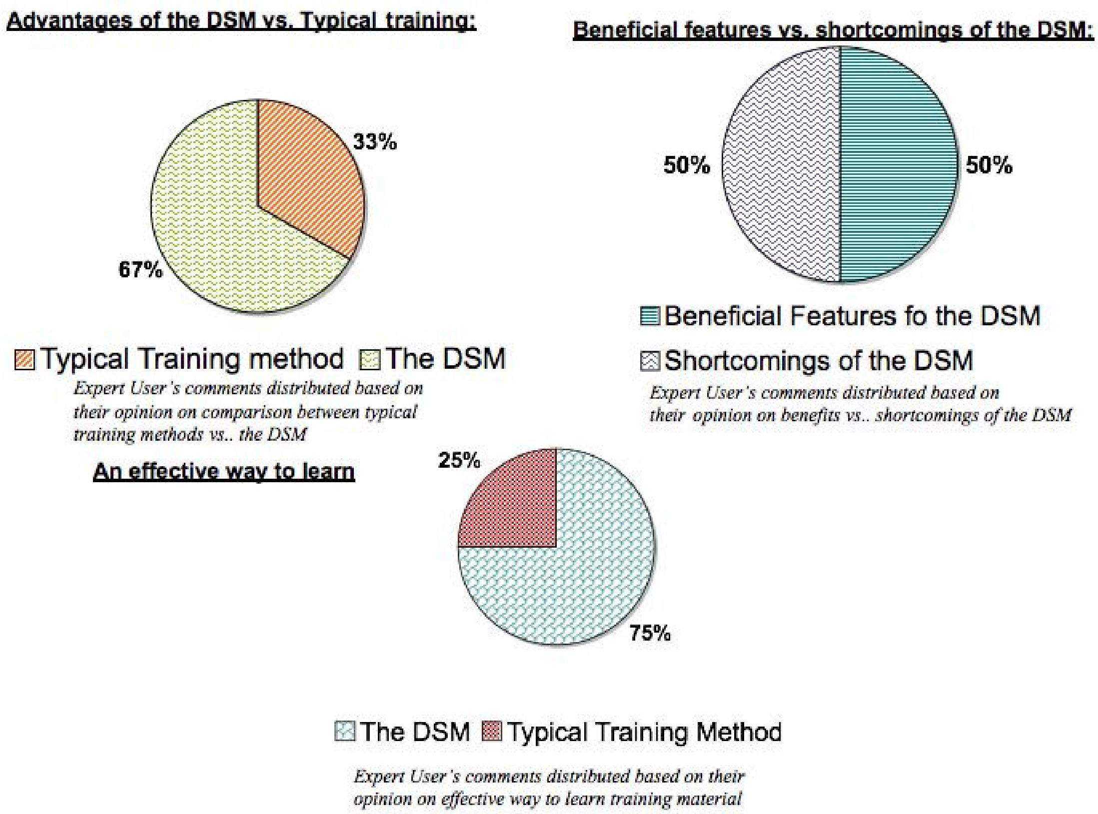


Figure 29: Percentage distribution of the Expert user's comments on the Qualitative Comparison Survey

The findings that were received after expert users qualitative comparison between two learning approaches were analyzed and documented as shown in Table 5 and Figure 29. The overall results of the qualitative comparison between the DSM and the typical training method are largely positive. 67% of the comments that were received from the industry experts said that definitely there are more advantages of the DSM over the typical training method while 33% comments received indicated that the typical training method is more preferable.

When asked about the beneficial features and the shortcomings of the DSM, the comments that were received from the industry experts were equal. 75% of the comments that were received from the industry experts said that the DSM is an effective and interesting way to learn the training material where as 25% of their comments were advocating the benefits of the typical training method.

After analyzing these comments, it can be said that the industry experts saw potential in this new approach of learning the subject matter.

6.3.3 Summary of the Results

Pilot test of Usability Evaluations (Novice & Experts):

The summary of the analysis of results yield after conducting the usability evaluation methods for the DSM prototype is as follows:

- Navigation is easy and easy to get used to with little improvement on the clarity of the instructions presented for the exploration of the DSM.
- Overall design/layout of the DSM is very interesting and intuitive but some minor changes could make it user-friendly.
- Some of the most liked things about the DSM are; interactive, self-paced, non-linear, flexible, accessible, easy to update, use of videos & pictures along with the text, etc.
- Some of the least liked things about the DSM are; not structured, no system to track user performance, navigational bugs, repetition of the information, not all the information is accessible since it's a prototype, etc.
- This concept definitely has potential and applicability not only in mining industry but in construction industry as well.
- Gen X was more comfortable with the navigational issues and the uniqueness of the design as compared to the industry professionals.

Subjective Analysis (Novice & Experts):

The summary of the analysis of the results yield after conducting the subjective analysis to compare the DSM and the typical training method is as follows:

- Definitely more advantages in using the DSM over the typical training method.
- The DSM could be used as a supplementary training material along with the typical training method.
- More structured approach is needed
- Need to have ability to track user performance and knowledge gained quiz as part of the DSM.

Chapter 7: Limitations & Future Work

Chapter 7: Limitations & Future Work

7.1 Limitations of this Research Work:

Based on the analysis results in Chapter 6 (section 6.3) this research has identified some limitations. Some of the limitations are due to limited technological skills such as no experience in computer programming, time limitation to explore the capabilities of other better softwares etc. But the most significant limitation of this research work is the absence of performance-based (objective) analysis of the user's learning ability assessment. This was due to following reasons:

- The scope of this research was to measure the potential by developing the prototype as a proof-of-concept rather than developing one or more complete training modules to conduct performance based (objective) analysis.
- The DSM prototype would not have been able to accurately measure the user's learning ability due to lack of complete information module. It would have been difficult to distinguish if the users performance was either positive or negative due to the incompleteness of the implementation or whether the way the application was organized/designed prevented the user not to perform better.

By conducting the subjective analysis this research work proved the potential of the concept by qualitatively comparing the two training approaches; typical training method, and the Digital Safety Manual. The performance-based analysis will help in satisfying the larger goal of this research; to measure the user's learning ability (knowledge retention) by comparing both the training approaches. It will be a fact-based analysis regardless of the opinions of the users.

The results of the subjective analysis underlined the need for further development to explore the potential of the DSM as a better approach to learn the information. In order to explore the complete potential (usability & better knowledge retention) future work is identified below:

7.2 <u>Future Research Areas:</u>

To address the limitations discussed above we have proposed future research areas:

1. Further development of the DSM:

Data Analysis

	Subjective (Opinion Based)	*Objective (Fact based)*
Qualitative		Scope of the future work
Quantitative		Scope of the Future work

Figure 30: Data analysis table

The prototype can be used as a template/framework to completely or partially develop one or more information modules of the Digital Safety Manual application so that it can be objectively analyzed against the typical training method (See Figure 30). An objective analysis will help in determining user's knowledge retention capacity and transfer of knowledge on the job site. This will validate this entire exercise as a better training approach.

The additional information will be gathered by conducting site visits to local mine operations. Once the DSM is equivalently developed as a training module; it will be put through series of formative usability evaluations and performance-based analysis to measure the applicability and effectiveness of this tool as a safety training application in mining industry.

A feedback and formative usability evaluation scheme (Figure 31) is proposed to guide the evaluation process. The evaluation scheme is divided into two phases;

- Formative Usability evaluations
- User's learning ability assessment.

Application evaluations will help in validating the information that is incorporated in the Digital Safety Manual and it's interface related usability issues. Whereas user's learning ability assessment will help in measuring the knowledge gain/retention comparison between typical learning vs. IT application (i.e. the DSM) for learning advantages.

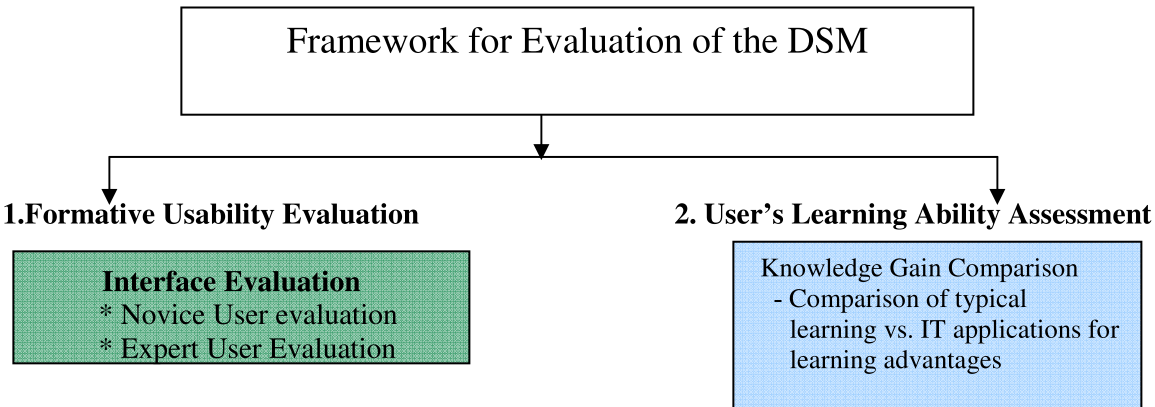


Figure 31: Proposed framework for Evaluation of the DSM

Phase 1: Application Evaluation:

The interface evaluation part is designed to gather the user's feedback and comments on various usability issues such as navigational controls, design/layout issues, etc. The participants for this phase of the evaluations will include both novice and expert users. This phase will involve approximately 20-25 students from various departments as novice users and around 15-20 industry professionals as expert users for this phase of the evaluation scheme.

A structured approach is proposed for the interface evaluation by breaking down this process into two sessions. As part of the first session a group of users will be given introduction of the application, what they need to do in the next session and navigational instructions on how to maneuver through the application. After this, in the second session these users will be given separate computers to explore the Digital Safety Manual and will be asked to explore the Digital Safety Manual. Once they are finished with session 2 they will be given a task sheet with tasks identified for them to find in the Digital Safety Manual. Following their exploration they will be given a similar questionnaire as used in the current work to assess the usability issues of the application. This process will be repeated with other groups of users to gather usability evaluations to develop the next iteration for the second part of the master evaluation scheme i.e. user's learning ability assessment.

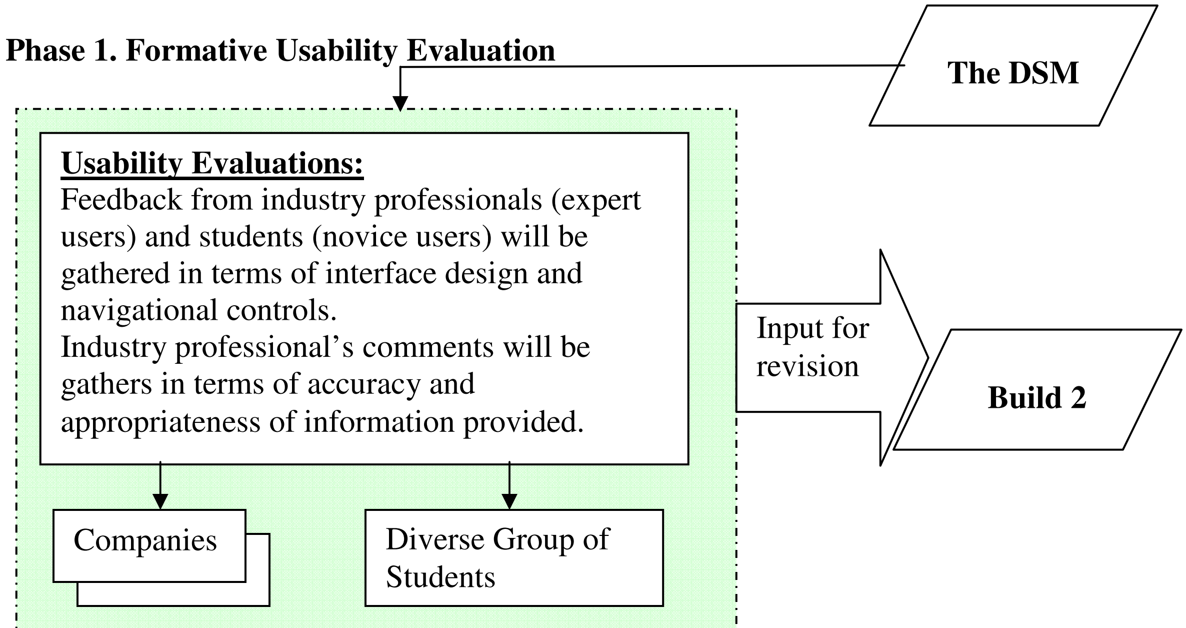


Figure 32: Details of Application Evaluation

Phase 2. User's Learning Ability Assessment (Performance-Based Analysis):

After collecting, reviewing, and synthesizing the data collected from application evaluation part; it will be used to develop the new iteration of the Digital Safety Manual. This new iteration of the Digital Safety Manual will be then used in a user 's learning ability assessment to compare the knowledge gained/retained by using IT based training applications vs. knowledge gained in traditional class room based training methods. This assessment is the most critical and important part of this research, as this will validate the effectiveness and efficiency of such training application depending on the results that will be achieved. At this stage of the assessment scheme two groups of users with no prior experience in the subject matter will be used (see Figure 33). The first group will be given a paper manual, binders, and loose photographs, videos that would be typically found in the industry as training delivery material, and the other group will be given a revised Digital Safety Manual to go through to simulate the training environment. After each group completed the designated form of learning they will be completing a general knowledge test. The general knowledge test will focus on the actual information that is important to know when one works in the conveyor belt environment and which is presented in some form or the other in both the training methods given to two groups for this assessment. The results from this general knowledge test will be then compared to see if there is an advantage of using one learning method over other.

This part of the evaluation scheme can also use VR-based application that is mentioned in the Chapter 1 (Section 1.2). This VR application is task-based and user are given pre-defined tasks to perform and after completing each task points are allocated to measure the user performance. It can be used as a computer-based test to compare the learning advantages between typical training methods and computer-based learning environment such as , the DSM.

Phase 2. User's Learning Ability Assessment (Performance-Based Analysis)

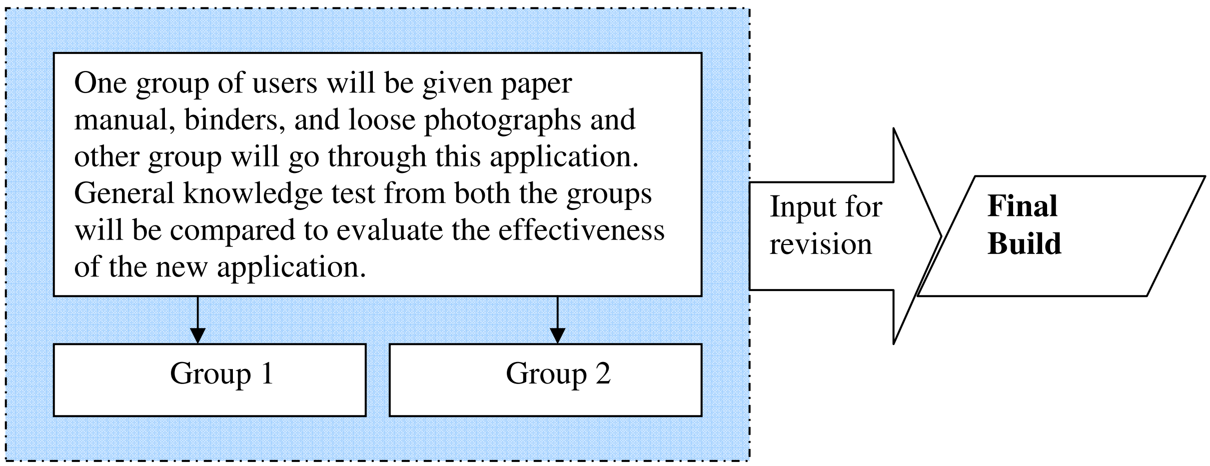


Figure 33: Details of. User's Learning Ability Assessment

This entire process will help determine the actual objective of this research project, use of interactive multimedia-based learning tool to enhance knowledge retention and increase the cognitive learning of the user. At the end of the evaluation process the DSM will be revised based on the comments and suggestions gathered from the novice and expert users. Then the DSM will be distributed to our industrial partners.

2. ***Learning Management Systems (LMS):***

Consider using this application as a Learning Management System (LMS) for the trainers. A learning management system (LMS) is a software application or Web-based technology used to plan, implement, and assess a specific learning process. Typically, a learning management system provides an instructor with a way to create and deliver content, monitor student participation, and assesses student performance. A learning management system may also provide students with the ability to use interactive features such as threaded discussions, video conferencing, and discussion forums.

Also, Add capability to add end of session quizzes to measure the user's performance of knowledge retention. Also, develop a system where users exploration path can be tracked and documented. This will allow trainer to measure the user performance and keep track of all the training documents. Also, it will validate this tool as a proper training method.

3. ***Dynamic capabilities:***

   a. *Data Retrieval:*

   Incorporate computer programming to make the DSM a more dynamic application where users can find particular information from various databases by using search command. These databases can be integrated with the manufactures and could be updated from time to time with the advancements in the conveyor belt safety area. Explore the concept similar to the wikipedia (open database) where different individuals can contribute to the information database.

b. Data customization:

Also add a feature where the user can add/capture their comments so that it could be customizable to their individual needs.

4. Dissemination of information:

Dissemination of information is an important factor that needs to be considered in computer-based self-learning applications. Further research needs to address following factors:

- Need for on-location (job site) access to the information
- Dissemination platform to output the application.

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Appendix A: Summary Review of Belt Related Fatal Accidents Between 1995-2007

Accident Category	MSHA Case References	Maintenance Task Performed	Belt Assembly contributing to accident	Accident Scenario
1.0 Entanglement	M-1996-21	Cleaning - spilled and built-up material	Head pulley	The miner climbed onto the conveyor to shovel off material. The conveyor started, and the miner was transported approximately 150' where he was caught in an 8" gap between the head pulley cross member and the pulley.
	C-1996-7	Installation/repair	Power rollers	During the repairing of conveyor belt, the miner was pushing on the belt with his hands to maintain tension between the belt and power rollers to help feed the belt thru the tandem drive rollers on the belt drive. He became entangled between the two power rollers of a belt conveyor drive.
	C-1997-27	Installation/repair	Drive motor	The miner was standing on the belt conveyor structure beside the drive roller sprocket, while performing repair work on broken chain between the drive motor and drive roller. The drive motor unexpectedly became energized and the miner became entangled in the drive unit. The electrical power to the drive had not been locked out and tagged, and the drive unit had not been blocked against motion.
	M-1996-16	Installation/repair	Crusher	While helping in setting up two portable crushers, the miner got crushed between two crushing units.
	M-1997-7	Cleaning - spilled and built-up material	Tail pulley	The actual reason for the accident is not known as there are no eyewitnesses but it is believed that the miner was working around energized conveyor belt. The victim became entangled in an unguarded tail pulley and died.
	M-1997-29	Loading of pit material in the feed hopper	Return idler	A truck with load of pit material was loading material in the feed hopper. While raising the truck bed truck driver noticed the screen feed conveyor surging. After getting down from the truck he saw the victim's right arm had become entangled between unguarded return idler and conveyor belt. How accident happened is not clear, as there was no eyewitness.
	M-1997-18	Belt alignment	Tail pulley	The miner went underneath the unguarded portion of the belt to the adjustment bolt on the East side of the tail pulley as the belt was starting to untrack because of built up material in the wings of the pulley. The victim became entangled in an unguarded tail pulley while conveyor was in motion and died.
	M-1997-2	Cleaning - spilled and built-up material	Tail pulley	The victim was caught in an unguarded tail pulley of the crusher belt and died. There are no eyewitnesses to the accident but it appears that the miner was attempting to remove frozen material from the moving belt while belt was in motion.
	M-1998-17	Cleaning – spilled and built up	Drive pulley and bend	Accident occurred due to failure to de-energize the conveyor before cleaning. The victim's arm

		material	pulley	got pulled into pinch points between unguarded drive pulley & the bend pulley.
	M-1998-20	Cleaning – belt assembly	Return idler	While cleaning return idler, the victim was caught and drawn into pinch point between unguarded return idler and moving belt.
	M-1998-14	Cleaning – spilled and built up material	Tail pulley	The victim was cleaning material from around an unguarded conveyor belt tail pulley under the crusher. The self-cleaning tail pulley caught his clothing, drawing him onto the conveyor and he was wedged between the conveyor and a tension (snubber) pulley.
	M-1999-12	Belt alignment	Return Idler	The victim's arms got caught and drawn between the unguarded return idler and the belt resulting into the death of the victim. Accident occurred due to failure to provide crossover to safely access both sides of conveyor.
	M-1999-31	Cleaning – belt assembly	Return idler	The victim was caught & drawn into the pinch point at an unguarded return roller wile conveyor was in motion.
	M-1999-52	Installation/repair	Self-cleaning pulley	The accident occurred due to entanglement of victim's clothes in an unguarded self-cleaning pulley. The victim had entered into a confined space area containing an unguarded self-cleaning pulley that was in operation to shovel the spilled material from along side of the conveyor belt.
	M-2000-13	Maintenance of service equipment	Tail pulley	While working on the maintenance of a front end loader (used for cleaning and clearing material around the belt), Accident occurred due to entanglement in an unguarded tail pulley while conveyor was in motion.
	M-2000-12	Belt alignment	Bend pulley	The victim and a co-worker were making adjustments to a new conveyor installation. The victim was aligning the extended grease lines for the bend pulley from inside the conveyor frame. The victim became entangled in the unguarded bend pulley and died.
	M-2001-2	Cleaning – spilled and built up material	belt	Accident was caused by the failure to de-energize the power to the conveyor. The victim became entangled in a conveyor belt and died.
	M-2001-26	Cleaning – spilled and built up material	Take-up pulley	Accident occurred because maintenance was being performed while conveyor components were in motion. The victim became entangled in the discharge belt take up pulley and died.
	C-2001-7	Inspection	Take-up pulley	Accident occurred during an examination of a 54" belt conveyor drive take-up unit while the belt conveyor was still in motion. The rotating rollers of the belt conveyor take-up unit detached the victim's left arm.
	M-2002-16		Conveyor snub pulley	While monitoring the stockpiling of crushed ore over feeders, the victim was fatally injured at an open pit copper operation. His shovel became entangled in an unguarded conveyor snub pulley.
	M-2002-29	Cleaning – spilled and built up material	Tail pulley	Accident occurred while the victim was removing fines that had packed around a winged type tail pulley of a belt. As the spillage was removed, the bound conveyor belt moved backward a short distance and caught the victim's arm between the belt and the tail pulley.
	M-2005-1	Cleaning – spilled and built up material	Return idler	Worker was cleaning spilled material underneath the conveyor belt. Accident occurred because a guard had not been installed on the return idler.

				The miner was cleaning spilled material underneath the moving belt and became entangled in an unguarded return idler.
	M-2005-20	Cleaning – spilled and built up material	Return idler	Accident occurred when miner was cleaning up the built-up material on a return idler. His shovel got caught between moving belt and return idler.
	M-2005-18	Belt alignment	Tail pulley	Worker was making adjustments to the belt. Accident occurred due to performing repair work around an unguarded tail pulley. The victim's arm became entangled in the moving belt and tail pulley.
	M-2006-5	Cleaning – spilled and built up material	Tail pulley	Accident occurred when the victim entered the area under the crusher and travelled near the backside of the discharge conveyor tail pulley to clean the spillage beneath the crusher discharge from the sides of the conveyor tail pulley and his clothing became entangled in the rotating tail pulley.
	M-2006-9	Installation/repair	Return idler	Worker was adjusting the return idlers while the belt was in motion. He became entangled between the belt and the return idler.
	C-2004-19	Installation/repair	Tail pulley	Accident occurred while the miner was trying to install belt scraper at a tailpiece while the belt was in motion. A chain attached to the scraper was caught by the belt, dragging it and the victim into the tail pulley.
	M-25-2007	Cleaning	Take-up Pulley	Accident occurred while the victim was trying to shovel spilled material behind an unguarded take-up pulley. His shovel got entangled in between an unguarded take-up pulley and moving belt.
2.0 Collapse of structure, belt components or falling material	M-1997-20	Sampling	conveyor belt	A worker was sampling material coming off the bin feeder. The discharge conveyor belt under the storage bin was running and caused the material within the bin to slide and engulf the miner. The victim died from suffocation.
	M-1997-15	Installation/repair		A large portion of roof and rib (22 feet long x 42 inches wide x 26 inches thick), fell onto the miner resulting in fatal injury.
	M-1997-13	Installation/repair	Drive unit	While installing belt conveyor drive unit the chain on the lever hoist holding the boom suddenly broke and the boom section swung toward the drive unit crushing the miner against the drive roller.
	M-2000-3	Cleaning – belt assembly	Shaft kiln draw floor	Accident occurred while cleaning of the shaft kiln draw floor. Accident was caused by the failure to lock out the tripper conveyor and block the counterweight against motion before cleaning the guarded framework. The victim was crushed between a descending counterweight and counterweight's guard.
	M-2001-29	Cleaning –	Feed hopper	The victim was pounding on the sides of the hopper with a bar and hammer and working from the elevated bucket of the front end loader attempting to free the flow of materials inside the primary feed hopper. The victim entered the feed hopper to dislodge a hang up, when he was engulfed by material and suffocated.
	M-2002-19	Installation/repair	belt	Victim was repairing portable conveyor system. Accident occurred due to removing of a support

				structure on a portable conveyor. The conveyor was positioned on a hydraulic jack supported by two wooden blocks when it shifted and fell crushing the victim.
	M-2002-40	Installation/repair	Belt walkway	Victim was engaged in the removal of lower sections of walkway near tail pulley for replacement. Accident occurred when the walkway section collapsed killing the worker.
	M-2004-11	Cleaning – spilled and built up material	Hopper	While clearing the blockage of material at discharge chute accident occurred when the victim entered the hopper from the top without wearing a secured safety harness and lanyard when the material suddenly gave way and engulfed him.
	M-2004-19	Cleaning – spilled and built up material	belt	The victim was using a water hose to clean spillage under a conveyor. A large rock fell from a conveyor located overhead and struck him, resulting in fatal injuries.
	M-2004-9	Installation/repair	Crusher/belt	The victim was dismantling a crusher. Accident occurred when the victim was attempting to remove the pin from a support arm, was struck by a portion of the conveyor resulting in fatal injury.
	M-2006-24	Installation/repair	Head pulley	Worker was standing underneath the head pulley section of a conveyor preparing to attach a chain that was to be used to move the conveyor. The accident occurred when the bolts connecting the conveyor truss sections in the conveyor's frame failed, causing the head pulley section to fall and strike the victim.
	M-2001-12	Installation/repair		The victim was fatally injured while helping to assemble the plant. Accident occurred due to failure to provide suitable rigging equipment and to properly attach it to the load being hoisted. Need more explanation to show falling parts.
3. 0 Falling from height	M-1995-36	Installation/repair	Take-up pulley	A cement take-up pulley weight for a conveyer was being lifted into position by a crane. The miner was riding on the 3,000-pound weight as it was being lifted. One of the pins pulled out of the weight causing the miner to lose his balance and fall 35 feet to the ground.
	C-1995-41	Cleaning - spilled and built-up material	belt	The belt structure was being used to route and sort coal at the discharge locations where the different grades of coal are discharged and stored on the ground. Six miners were shovelling the coal spillage when the belt structure shifted, broke free, and fell. One miner fell with the collapsed structure and died.
	C-1995-21		belt	A roof-bolting machine operator was attempting to cross a moving conveyor belt. The miner lost his balance and fell onto the belt, which carried him over a head roller, resulting in fatal injuries.
	M-1996-20	Installation/repair		The miner was working on an elevated crusher installing bolts in the I-beam supports for the crusher hopper. He slipped off the crusher and fell 15 feet to the ground resulting in fatal injury.
	M-2004-16	Installation/repair	belt	During the installation of conveyor belt, the victim was standing on the steel support structure for the conveyor and fell 12 feet when the rope he was pulling unexpectedly came loose from the end of the belt.

4.0 Miscellaneous	M-2002-12	Cleaning – spilled and built up material	belt	Worker was clearing a blockage inside a cement clinker drag conveyor located in a tunnel. The victim got fatally burned due to outburst of the steam.
	M-2006-11	Installation/repair		Victim was working from the bucket of a front-end loader to install a roller on a conveyor belt 15 feet above ground. Accident occurred when the loader moved forward crushing the victim against the conveyor framework.
	M-2005-31			The victim was moving a radial stacking conveyor to a new location. He was fatally injured when the wheels of the conveyor got stuck and rolled over him.
	C-2005-6	Cleaning – other		Worker was removing a piece of canvas that was wrapped around the section feeder rotary pick breaker. Accident occurred when the rotary breaker started pulling the victim under the picker.
	C-2004-8	Cleaning – belt assembly		Accident occurred due to performing belt-cleaning task on the moving conveyor belt. This is not clear. We need more explanation

Appendix B: Summary of age and experience of the miners involved in the belt related fatal accidents between 1995-2007

Accident Category	MSHA Case References	Maintenance Task Performed	Belt Assembly contributing to accident	Age	Experience
1.0 Entanglement	M-1996-21	Cleaning - spilled and built-up material	Head pulley	41	10 yrs
	C-1996-7	Installation/repair	Power rollers		
	C-1996-27	Installation/repair	Drive motor		23 yrs
	M-1996-16	Installation/repair	Crusher	25	19 months
	M-1997-7	Cleaning - spilled and built-up material	Tail pulley	36	9 months
	M-1997-29	Loading of pit material in the feed hopper	Return idler	27	2 yrs
	M-1997-18	Belt alignment	Tail pulley	40	11 yrs
	M-1997-2	Cleaning - spilled and built-up material	Tail pulley	47	2 yrs
	M-1998-17	Cleaning – spilled and built up material	Drive pulley and bend pulley	36	2 yrs
	M-1998-20	Cleaning – belt assembly	Return idler	57	36 yrs
	M-1998-14	Cleaning – spilled and built up material	Tail pulley	47	2 months
	M-1999-12	Belt alignment	Return Idler	56	4 weeks
	M-1999-31	Cleaning – belt assembly	Return idler	25	4 weeks
	M-1999-52	Installation/repair	Self-cleaning pulley	22	2 weeks
	M-2000-13	Maintenance of service equipment	Tail pulley	18	1 yrs
	M-2000-12	Belt alignment	Bend pulley	38	4 yrs
	M-2001-2	Cleaning – spilled and built up material	belt	21	8 months
	M-2001-26	Cleaning – spilled and built up material	Take-up pulley	36	5 weeks
	C-2001-7	Inspection	Take-up pulley	45	22 yrs
	M-2002-16		Conveyor snub pulley	32	5 yrs
	M-2002-29	Cleaning – spilled and built up material	Tail pulley	43	17 months
	M-2005-1	Cleaning – spilled and built up material	Return idler	49	14 yrs
	M-2005-20	Cleaning – spilled and built up material	Return idler	30	8 weeks
	M-2005-18	Belt alignment	Tail pulley	31	2 yrs
	M-2006-5	Cleaning – spilled and built up	Tail pulley	23	1 month

		material			
	M-2006-9	Installation/repair	Return idler	19	4 weeks
	C-2004-19	Installation/repair	Tail pulley	46	12 yrs
	M-25-2007	Cleaning	Take-up Pulley	42	32 yrs
2.0 Collapse of structure, belt components or falling material	M-1997-20	Sampling	conveyor belt	49	30 days
	M-1997-15	Installation/repair			
	M-1997-13	Installation/repair	Drive unit		
	M-2000-3	Cleaning – belt assembly	Shaft kiln draw floor	37	3.5 yrs
	M-2001-29	Cleaning –	Feed hopper	52	5 yrs
	M-2002-19	Installation/repair	belt	51	21 weeks
	M-2002-40	Installation/repair	Belt walkway	47	1 yr 10 months
	M-2004-11	Cleaning – spilled and built up material	Hopper	33	3 yrs
	M-2004-19	Cleaning – spilled and built up material	belt	64	17 yrs
	M-2004-9	Installation/repair	Crusher/belt	37	4 yrs
	M-2006-24	Installation/repair	Head pulley	41	4 yrs
	M-2001-12	Installation/repair		39	2 yrs
3. 0 Falling from height	M-1995-36	Installation/repair	Take-up pulley	52	22 yrs
	C-1995-41	Cleaning - spilled and built-up material	belt		
	C-1995-21		belt		
	M-1996-20	Installation/repair		52	12 yrs
	M-2004-16	Installation/repair	belt	63	45 yrs
4.0 Miscellaneous	M-2002-12	Cleaning – spilled and built up material	belt	67	29 yrs
	M-2006-11	Installation/repair		44	11 yrs
	M-2005-31			32	7 yrs
	C-2005-6	Cleaning – other		42	3 yrs
	C-2004-8	Cleaning – belt assembly		57	30 yrs

Appendix C: *Usability Evaluations Questionnaire*

Digital Safety Manual (DSM) Prototype

Usability Evaluation Questionnaire	**Demographics**

Note: Demographics are only going to be used to track trends, no personal information will be released with out prior consent of an individual.

- What is your gender? (Circle One) Male Female
- What is your age? ______________
- What is your occupation? (Student please list degree and major)

- Have you used any multimedia-based applications before?

(A multi-media application is an application where information is presented using different medias such as text, images, videos, animations, URL links, etc.)

Yes No

- If yes, please explain briefly

- Have you taken any type of training course that was interactive or multimedia based?

Yes No

- If yes, please explain what type of training course it was.

- Do you surf the Internet?

Yes No

Usability Evaluation Questionnaire	Digital Safety Manual prototype

After completing the exploration of the Digital Safety Manual (DSM) prototype please answer the following questions to the best of your ability. Use blank space at the end of the questionnaire for additional comments and suggestions.

Navigational Questions:

1. The navigational instructions were easy to understand and sufficient.
   (The navigation instructions those are included in the introduction screen as well as at the bottom of each screen).

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

   If you *disagree or strongly disagree* please explain why?

   ____

   ____

2. Navigation is simple and easy to use and easy to get used to.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

Design/Layout Questions:

3. The overall screen organizational layout design is consistent.
   (e.g. locations of buttons, title of the screens, colors, etc.)

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

   If you *disagree or strongly disagree* please explain why?

   ____

   ____

4. The text size and font color is consistent and readable.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

   If you *disagree or strongly disagree* please explain why?

   ____

   ____

5. The information presented is understandable. (The text, images, videos, menus, etc.)

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

If you *disagree or strongly disagree* please explain why?

____

____

6. It is easy to understand the relationship between information in the categories.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

If you *disagree or strongly disagree* please explain why?

____

____

7. The color-coding of the bars is helpful to draw the link between the categories and information.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

If you *disagree or strongly disagree* please explain why?

____

____

8. The height of the bars represents amount of information that it contains is easy to understand.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

If you *disagree or strongly disagree* please explain why?

____

____

9. Use of multi-media (i.e. text, images, videos, URL links, animations, etc) is effective to present safety information.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

If you *disagree or strongly disagree* please explain why?

10. The hierarchical organizational flowchart button on each screen to identify your position in the matrix navigation is easy to locate on every screen and is useful.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

If you *disagree or strongly disagree* please explain why?

General Questions:

11. DSM exploration is an interesting and an engaging experience.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

If you *disagree or strongly disagree* please explain why?

12. What are the three things you liked the most about the DSM?

13. What are the three things you liked the least about the DSM?

14. What other application do you see the concept of the DSM applied to in our Construction Industry?

15. Please provide us with general comments and suggestions to improve quality and experience of the DSM.

This section is only for (Industry Experts)

Information Review Questionnaire	Digital Safety Manual prototype

1. The information presented in Belt Conveyors category is appropriate and complete in terms of text, images, videos, statistics, etc.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

2. Please provide any additional comments or suggestions for this category (Belt Conveyors)

3. The information presented in Possible Hazards category is appropriate and complete in terms of text, images, videos, statistics, etc.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

4. Please provide any additional comments or suggestions for this category (Possible Hazards)

5. The information presented in General Safety Practices category is appropriate and complete in terms of text, images, videos, statistics, etc.

1	*2*	*3*	*4*	*5*
Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*

6. Please provide any additional comments or suggestions for this category (General Safety Practices)

7. Please provide any additional comments or suggestions for overall information presented in the Digital Safety Manual

Appendix D: *Qualitative Comparison Questionnaire*

Training Method Comparison – Qualitative Survey No. ______

Reviewed Application☐ Digital Safety Manual☐ Virtual Reality Training

Please answer to the best of your ability as how you perceive the reviewed application will work within the industry compared to typical training material.

1. What are some of the advantages of a typical training method you are familiar with over the reviewed application?

____

____

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2. What are some of the advantages of the reviewed prototype application over the typical training methods?

____

____

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____

3. What features of the reviewed application do you see as the most beneficial for learning the training material?

____

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____

4. What challenges/shortcomings do you see in learning the training material using the reviewed application? And how can these be corrected?

____

____

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____

____

5. Do you think the proposed training application is an effective way to learn the material? Why or why not?

____

6. Which method of training do you perceive as a more effective way of learning? Why?