An Integration of Lean Six Sigma and Health and Safety Management System in Saudi Broadcasting Corporation

A thesis Submitted for the degree of Doctor of Philosophy

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ABSTRACT

Lean Six Sigma is a method used to improve the quality and efficiency of processes by reducing variation and eliminating wastes (non-value added activities) in an organisation. The concept of combining the principles and tools of Lean Enterprise and Six Sigma has been discussed in the literature. The majority of Lean Six Sigma applications in private industry have focused primarily on manufacturing applications. The literature has not provided a framework for implementing Lean Six Sigma programmes in non-manufacturing or transactional processes like those in the Entertainment Media industry. The Saudi Broadcasting Corporation (SBC), like many other industries in Saudi Arabia, has high occupational safety risks, such as electric, fire and fall hazards which often occur in the media workplace. These risks are considered very costly and affect productivity and employee morale in general.

The main objective of this research is to provide a synergistic approach to integrating occupational health and safety programmes and Lean Six Sigma tools using the DMAIC (Define-Measure-Analyse-Improve-Control) problem-solving method to strengthen and assure the success of safety programmes in the Saudi Broadcasting Corporation (SBC).

This research identifies the roadmap (i.e. activities, principles, tools, and important component factors) for applying Lean Six Sigma tools in the media industry. A case study addressing the safety issues that affect employees' performance within the Saudi Broadcasting Corporation (SBC) TV studio is used to validate work outlined in this research. Furthermore, the Bayesian Belief Networks (BBN) method is used to understand the probability occurrence of safety hazards. The application of the Taguchi Experimental Design method and other Lean Six Sigma tools, such as Cause and Effect diagrams, Pareto principles, 5S, Value Stream map, and Poka-Yoke have been incorporated in to this research.

The application of Lean Six Sigma DMAIC problem-solving tools resulted in significant improvement in safety within SBC. The average electrical hazard incident decreased from 2.08 to 0.33, the average fire hazard incident decreased from 1.25 to 0.08, and the average fall hazard incident decreased from 3.42 to 0.17. The research has important implications for the company and its employees, with positive outcomes and feedback reported by top management, the senior technicians, and experts. The research improved the safety by reducing electrical, fire and fall risks. The Safety training sessions are one of the most significant factors that improve their safety awareness. It is observed that Lean Six Sigma problem-solving tools and methods are effective in the Saudi Broadcasting Corporation (SBC).

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DEDICATION

I dedicate my work to **Mr. Saad Aifan Alharthi** who is my father, brother and friend, and I also dedicate my thesis to my **mother**, sisters, brothers, daughters (Haya & Lana) and wife who encouraged me to complete this work.

AUTHOR'S DECLARATION

I hereby certify that this material, which I now submit for assessment for the programme of study leading to the award of Ph.D., is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

LIST OF ABBREVIATIONS

SBC	Saudi Broadcasting Corporation
LSS	Lean Six Sigma
OHSMS	Occupational Health and Safety Management System
FBD	Fishbone Diagrams, Ishikawa diagrams, herringbone diagrams and cause-and-effect diagrams
FMEA	Failure Mode and Effect Analysis
BBN	Bayesian belief network
ANOVA	Analysis of Variance
5S	5 components: seiri (sort), seiton (set in order), seiso (shine), sieketsu (standardise) and shitsuke (sustain)
VSM	Value Stream Mapping
SPC	Statistical Process Control
Ina T	Inadequate training
LE	Lack of experience
DA	Disorganised area
OV_Load	Overload
BM	Bad maintenance
OV_Heat	Overheating

Old_equip	Old equipment
B_Con	Using Bad connector
L_Prot	Lack of protections
L_Det	Lack of Detections
Flam_Mat	Using Flammable Materials
Décor_P	Décor Problems
HP	Handling problems
S_Weakness	Safety inspection Weakness
TP	Tooling problems

CHAPTER 1 : INTRODUCTION

1.1 Introduction

Saudi Arabia has become one of the biggest technology, communications and media (TCM) markets in the Middle East and Africa region. The media industry has seen great growth and development. As a result, there is greater need to have an occupational health and safety systems programme to support such development and to prevent health and safety problems.

The Saudi Broadcasting Corporation has high levels of occupational safety risks, particularly because Saudi Arabia has desert weather, which leads to overexposure to heat and dusts, causing chronic diseases, disabilities or even death in some cases. Dusts reduce the quality of the produced films or other types of produced media and the high temperature causes fire hazards. There are other safety hazards, like falling and electrical hazards, which often occur in the media workplace, resulting from tangled cables in the studio because it is filled with machines and equipment, each of which has its own set of cables to supply it with electricity. These cables pose a great danger to workers, and also damaged cables or electrical equipment will be a real danger to the life of all the employees. Dealing with media equipment like cameras, lighting systems, and electrical generators involves high risks too. Electrical connections and machinery are also included in this category. All employees may be endangered by these hazards.

Due to the high level of safety hazards, it is necessary to implement an effective Health and Safety Management System to minimise hazard risks to employees. These risks are considered very costly and affect productivity and employee morale in general.

Many occupational health and safety programmes have been developed and implemented with little success. Combining occupational health and safety programmes with Lean Six Sigma process improvement methods will enforce, strengthen and assure the success of these programmes, and this is the main aim of this research.

1.2 The Importance of this Research

Lean Six Sigma philosophy and tools have been applied successfully in many organisations and government agencies. However, the literature does not provide a framework for implementing Lean Six Sigma in TV studios. The researcher's intention is to show that Lean Six sigma tools are suitable for application in transactional processes, and that they complement any health and safety programmes by eliminating and reducing safety hazards like electric, fire and falling.

1.3 The Purpose of this Research

The Saudi Broadcasting Corporation manages several radio and television stations and has decided to prioritise and address worker health and safety. The main objective of the Saudi Broadcasting Corporation is to reduce safety risks overall using continuous process improvement such Lean Six Sigma. This research tests the hypothesis that the application of Lean Six Sigma tools and principles in a transaction-based environment, such as a TV studio, is effective and successful. Also, this research offers a new methodological approach that integrates both established health and safety management systems and Lean Six Sigma techniques to identify and control potential hazards and to minimise accidents. The benefits of successful application are reductions in risks/hazards, and improved productivity, employee safety and morale.

The Saudi Broadcasting Corporation has tried to improve safety through the implementation of a zero-accident culture programme, to reinforce safety initiatives and assure programme success. Policies and procedures have been developed to support the programme.

A further objective of this research is to apply Lean Six Sigma tools in order to identify the root causes of safety hazards and eliminate them, minimising their harmful effects and therefore resulting in a safer workplace.

1.4 Research Problem

As the entertainment media industry is rapidly growing, it is experiencing more health and safety risks, and this has become a topic of increasing concern for the media industry in the Kingdom of Saudi Arabia. Due to the nature of the entertainment industry, the many variables and the uncontrolled environments of shootings, rehearsals, and events, there is always an element of safety risk. The risks in the entertainment and media industry involve falls, electrical hazards, flash lightning, fire, and many more. Table 1.1 below shows examples of these hazards and how frequently they occur. The risks result in low productivity and low employee morale, and cause the Saudi Broadcasting Corporation to incur high costs annually. The media industry consists of radio, TV, and cable broadcasters. The scope of this study covers motion picture/television production and distribution, which includes major studios, independent film production companies, and television production, including reality television.

Table 1-1 Sample of hazards in Saudi Broadcasting Corporation from SBC records sheet December 2011

Type of Hazard	**Frequency of Occurrence per Year (**December 2011)
Fall Hazards	36
Electrical Hazards	25
Fire caused Hazards	15
Outdoor Events Hazards	5
Fatigue Hazards	4
Noise Hazards	3
Laser Hazards	2

1.5 Research Aim and Objectives

Occupational Health and Safety Management Systems (OSH-MS) are an integral part of any organisation, especially in media industries which are not immune to dangerous hazards. Electricity, fire, and falling are among these hazards. It is important for OSH systems to improve employees' performance and safety and decrease the costs associated with these hazards.

The Lean Six Sigma DMAIC application has been used to reduce and mitigate these risks, and to implement behaviour-based safety in the workplace; it is a proactive approach to addressing safety issues and to promoting and achieving a culture of safe behaviour in any organisation. Understanding the above facts, the research aim and objectives have been identified as follows.

a) Research Aim

The aim of this research is to develop a sound methodology and also practical, suitable tools for the integration of Lean Six Sigma with the existing health and safety management systems for eliminating and reducing safety hazards like electricity, fire and falling in the media industry environment.

b) The Objectives of this Research

The main objectives of this research are:

- To develop a methodology for the integration of both established health and safety management systems and Lean Six Sigma techniques to identify and control potential hazards and minimise accidents in SBC.

- To prevent and reduce safety hazards and risks in SBC by using a combination of Cause and Effect analysis, FMEA, Pareto principles and Bayesian Belief Networks (BNNs), etc.

- To gain deep knowledge of the importance and significance of various factors in the management of fire hazards using the Taguchi method and Design of Experiment (DOE).

- To utilise the Bayesian Belief Network to model and simulate the major causes of electric fire, and fall hazards in the SBC, together with the sensitivity and what-if analysis.

- To employ Statistical Process Control (SPC) to control and continually improve the key process performances in the management of safety hazards.

1.6 Research Structure

This chapter has introduced the purpose of the research along with the overall research aim and related objectives. The thesis comprises of five chapters. Chapter 2 is an important review of the literature concerning quality improvement philosophies and tools. A key feature of this chapter will be to consider the critical factors required to successfully integrate Lean Six Sigma with Health and Safety programmes. Another feature will be to discuss the theoretical background of the Lean Six Sigma tools.

The third chapter addresses the research methodology of this study and its justification, and explains the multiple Lean Six Sigma methods used. The researcher has structured this study of media industry hazards using the Six Sigma DMAIC (Define, Measure, Analyse, Improve, and Control) model and associated methods. Statistical modelling is used to prioritise, explore, and lay the foundation for improving and controlling the identified hazards.

The fourth chapter covers the first three of the DMAIC Lean Six Sigma phases (Define, Measure, and Analyse) which are used to characterise the problem and formalise an understanding of health and safety risks as they exist in the Saudi Broadcasting Corporation site that is the subject of this research.

In the fifth chapter, the final two Lean Six Sigma phases DMAIC phases (Improve and Control) will be used to select, implement, and monitor the progress and the results of intervention strategies to address those risks. The knowledge learned in the Define, Measure and Analyse phases will be transferred and utilised in the improvement phase.

After understanding the root causes of the electric, fire and fall hazards, the aim is to eliminate or minimise their occurrences. Taguchi's method will be first applied to understand the significance of these causes and to identify the level required to minimise them. Next 5S is used to improve overall safety, followed by the Value Stream Map application to improve process efficiency, and the Poka-Yoke method to minimise human errors. C-chart is used to help verify the process improvement and to monitor processes to identify and eliminate assignable causes in order to sustain improvement. The following table summarises the work of chapter 4 and 5; it also outlines the objectives of each phase, and the method and the tools utilised in each phase.

Table 1-2 DMAIC framework

	DMAIC Phase	Objective	Methods
Chapter 4	Define	Define problem	• Project Charter
	Measure	Understand Current Process State	• Data Collection • Pareto Charting (All Hazards) • Value Stream Mapping
	Analyse	Analyse Root Cause of the Problem	• Cause and Effect Diagram • Process Failure Mode and Effects Analysis • Pareto Charting (Hazard Root Causes) • Bayesian Belief Network Analysis
Chapter 5	Improve	Improve Process Performance	• Taguchi Methodology • 5S Methodology • Value Stream Mapping • Poka-Yoke
	Control	Sustain Process Improvement	• Post Intervention Failure Mode and Effects Analysis • Post Intervention Bayesian Belief Network Analysis • Statistical Process Control: NP-Charts

In light of the findings in the previous two chapters, the final chapter concludes by summarising the findings and analysis and then validating that the objectives of the research have been met, especially the integration of Lean Six Sigma and the Occupational Health and Safety Management System, which proved to be an effective and successful application in the SBC. The findings in this study show that the SBC TV studio has many efficiency issues and safety hazards; Lean tools such as Value Stream Mapping, 5S etc. and Six Sigma tools such as DOE etc. have been used to improve the overall safety of its employees.

CHAPTER 2 : LITERATURE REVIEW

This chapter examines the current research activities in the integration of Lean Six Sigma (LSS) and Occupational Health and Safety Management Systems (OHSMS). The SBC TV studio has significant efficiency issues and safety hazards. It has been proposed that suitable Lean tools and Six Sigma tools will be used to improve the overall safety. Hence, this chapter provides a review of both OHSMS and Lean Six Sigma and their associated tools. The topics covered are as follows:

- Lean
- Six Sigma
- Lean Six Sigma
- Occupational Health and Safety Management Systems
- Lean Six Sigma and Occupational Health and Safety
- Ishikawa diagram
- Failure Mode and Effects Analysis (FMEA)
- Pareto principle
- Bayesian belief networks (BBN)
- Design of Experiment (DOE)
- 5S
- Value stream mapping (VSM)
- Poka-Yoke

In the literature review, different sources have been consulted, such as online databases, government documents, articles from the Internet, and companies' website information.

2.1 Lean

Lean is defined as the elimination of waste or non-value added activities in all sections of an organisation (Womack and Jones, 1994). This elimination of waste allows the organisation to become more efficient and well-organised, resulting in cost reductions in all areas of the company (Motwani, 2003). As a consequence, the company becomes more competitive and profit margins increase (Claycomb et al., 1999). This increased efficiency and competitiveness results in an increased market share, increased process outputs, improved quality and safety, and reduced resources.

Lean enterprise implementation can achieve long-term strategic gains, as demonstrated by Toyota's dramatic rise in the automotive industry (Smart et al., 2003). However, most companies implemented Lean not with the intent of gaining strategic competitiveness, but in order to obtain short-term cost reductions. The Lean implementation in the majority of companies is not systematic; on the contrary it is usually unplanned and unstructured (Chong et al., 2001). As a result, the overall company's performance decreases (Naslund, 2008) forcing the company to adopt an approach of seeking short-term efficiency gains (Smart et al., 2003). Often this short-term approach results in moving the wastage from one area to another rather than removing it completely (Harrison, 1999). Consequently, many recognise Lean implementation as simply a management method of obtaining cost-reductions (Achanga, 2006). Many questions have been raised regarding the purpose of Lean implementation as cost reduction instead of efficiency sustainability (Smart et al., 2003).

2.2 Six Sigma

Many researchers have studied Six Sigma methodology since its introduction in the late 1980's and have identified many success variables which are key to implementation. Six Sigma is defined as a management system for achieving customer satisfaction by improving processes with the aid of data and facts (The Six Sigma Way, 2003). The main idea of using the Six Sigma process is to improve customer satisfaction and also to increase profit margins (Banuelas et al., 2006). Six Sigma is a business system that focuses on customers; it is a fact- and data-driven process of improvement activities, and requires an active management involvement, and extensive team work.

2.2.1 Distinctions between Lean and Six Sigma

Lean and Six Sigma have much in common (Akbulut-Bailey et al., 2012; Ngo, 2010). For instance, they both emphasise customer orientation (Chiarini, 2011). Nonetheless, there remain significant distinctions (Ngo, 2010). Arguably the most important distinction pertains to the breadth of employee participation (Chiarini, 2011; Ngo, 2010). Six Sigma deployments are predominantly limited to a few highly trained professionals, while "Lean is shop floor driven" (Ngo, 2010).

2.2.2 Standard definition is lacking

Lean Six Sigma (LSS), while widely utilised, carries different meanings to different practitioners (Gershon, 2011). These differing expressions of LSS do not lend themselves to agreement on a standard definition (Assarlind et al., 2012; Gershon, 2011). The question of whether there should be "many types of [Lean Six Sigma] combinations depending upon organisational context, or can a universal model be developed" (Ngo, 2010) remains unanswered. Lean Six Sigma is generally defined as set of tools that assist companies to improve the quality and the efficiency of their processes (Salah et al., 2010).

2.2.3 Critical Success Factors of Lean Six Sigma

It is generally inferred that Lean Six Sigma consists of an integration of the two independent methodologies (Assarlind et al., 2012; Corbett, 2011; Gershon, 2011). Carreira and Trudell (2006) describe Lean Six Sigma as any combination of the tools and techniques of Lean and Six Sigma with the goal of continuous improvement. The expectation is that the merging of the two results in a magnified advantage.

There are a number of different ways in which the integration of the two methodologies is manifested "such as the integration needs to achieve combination of a philosophy of waste elimination with the attitude of perfection" Salah et al., (2010). LSS blends the Lean focus on process flow with the Six Sigma spotlight on improved capability by virtue of diminished variation (Chiarini, 2011; Oguz et al., 2012). Integration is not achieved when Lean and Six Sigma are alternatively deployed, as per menu options (Salah et al., 2010).

2.2.4 The Importance of this Research

Lean Six Sigma philosophy and tools have been applied successfully in many organisations and government agencies. However, the literature does not provide a framework for implementing Lean Six Sigma in TV studios. The researcher's intention is to show that Lean

Six Sigma tools are suitable for application in transactional processes and that they complement any health and safety programme by eliminating and reducing safety hazards like electric, fire and falling.

2.2.5 Defies Common Definition

As compared to Six Sigma DMAIC, the framework of the Lean methodology is less prescriptive (Ngo, 2010). Within Toyota, the concept of Lean – as the Toyota Production System is known outside of Toyota – has been characterised as a "formalisation and codification of experience and judgment" (Goh, 2011). Now, many years after the inception of Lean at Toyota, Lean methodology is being broadly practiced, yet there remain disparities between the many differing definitional viewpoints (Ngo, 2010).

As with Six Sigma, Lean is a methodology for the improvement of business processes and its purpose is to find and remove all waste (Gershon et al., 2011). For a period of time, Lean was held to be synonymous with the just-in-time philosophy (Ngo, 2010). On the other hand, some researchers perceive value stream mapping (VSM) as being synonymous with Lean (Pepper & Spedding, 2010). Other groups of researchers still stress that the Lean philosophy is a holistic approach (Mayeleff et al., 2012; Pepper & Spedding, 2010).

2.2.6 Implementation of the Six Sigma Model

The Toyota Production System was developed at Toyota Motor Manufacturing as far back as the middle of the last century, with Taiichi Ohno as the chief architect (Mayeleff et al., 2012). The mantel within Toyota was to eradicate all waste (Pepper & Spedding, 2010) with the aim of improving quality, which would lead to reduced costs and increased productivity, in accordance with the Deming Chain Reaction (Deming, 1986; Gershon et al., 2011). The Toyota Production System (TPS) was the forerunner for what is known today as Lean (Ngo, 2010; Pepper & Spedding, 2010). Prior to the assignment of the name Lean, the Toyota Production System was becoming more broadly studied and practised as a methodology entitled simply 'just-in-time' (JIT) (Gershon et al., 2011).

2.2.7 Guidelines for Implementing Six Sigma

Delivering products or services with an uninterrupted flow, with minimal waste, results in an efficient process with residual quality benefits (Antony, 2011; Corbett, 2011). The presence of waste is contrary to the objectives of Lean, resulting in inefficiencies such as long lead times, large inventories, long set-up times, equipment breakdowns, and quality problems leading to scrap and rework (Antony, 2010). Tools and techniques have been developed and affirmed for the implementation of Six Sigma (Antony, 2010; Assarlind et al., 2012).

Most Lean practising companies conduct problem-solving exercises in the form of organised projects, often referred to as ‘Kaizen’ events, wherein teams dedicate an uninterrupted period of time to the cause (Mayeleff et al., 2012). Kaizen events typically lead to quick gains, often with little data acquisition required (Hoerl & Gardner, 2010).

A key aspect of the Toyota Production System (TPS) is the principle of “respect for humanity” (Chiarini, 2011). The heart of TPS is the employees; they realise the Lean objectives under the coaching of management (Assarlind et al., 2012; Shah et al., 2008, Smalley, n.d.). In contrast to Six Sigma, employees do not need access to high-level statistical methods (Chiarini, 2011). While complex problems may be typically addressed with the Six Sigma methodology, Lean initiatives more frequently address “every day waste” and draw upon the participation of the broader base of employees (Corbett, 2011). This emphasis on full employee involvement means that Lean is regarded as a culture (Smalley, n.d.), rather than simply a collection of tools and techniques.

2.2.8 Search strategy

The search strategy for any literature is based on the identification of the relevant data sources and keywords. The databases used in this review included Scopus, ABI/Inform, IEEE Xplore, and Emerald. The search began with the choice of a set of keywords and possible combinations that could be pertinent to Six Sigma. The concept of Six Sigma embraces a very wide range of aspects and so a considerable number of search strings were deemed necessary. These captured all the aspects that characterise Six Sigma, such as definition, methodology, techniques, tools, implementation, enablers and issues. The keywords were related to other important concepts/tools so that connections from analyses would be included in the search results. Some examples of these tools include Lean, supply chain management, process management and sustainability.

2.2.9 Six Sigma implementation

Six Sigma was invented at Motorola and further advanced by General Electric (Akbulut-Bailey et al., 2012; Corbett, 2011). The impetus for the Six Sigma methodology was the need to reverse poor product quality trends, in order to assure organisational sustainability in the face of stiffening competition (Corbett, 2011; Goh, 2012). The Six Sigma methodology offers a quality enhancement and customer satisfaction plan (Antony, 2010; Goh, 2012) whose application has been broadened to cover all manner of business outcomes (Corbett, 2011; Dumitrescu & Dumitrache, 2011; Goh, 2010; Montgomery, 2010), with the superordinate goal of "bottom-line results" (Antony, 2010).

Six Sigma, as a name, not only represents an overall business methodology, but also represents a performance metric (sigma level) by which project success is measured (Chiarini, 2011), and by which a portfolio of future projects can be tracked and prioritised for improvement (Goh, 2010). A Six Sigma process is one in which the nearest specification limit is six standard deviations away from the process mean, at least in the short term (Montgomery, 2010).

The Six Sigma method of process improvement is realised by finding latent solutions to the causes of process errors (Antony, 2010; Hoerl & Gardner, 2010). Utilising a statistical, data-based scheme (Duarte et al., 2012; Goh, 2010; Hahn et al., 1999), the Six Sigma approach optimises processes by determining the relationship between critical process inputs and the essential process outputs, and resetting the inputs accordingly (Duarte et al., 2012; Oguz, et al., 2012).

The theoretical equation that represents the essence of the Six Sigma problem-solving method is $Y=f(X)$. The Y represents the process output and the X represents the critical inputs which drive the performance of the output. Understanding and controlling the pertinent inputs facilitate solutions which optimise the process outputs (Oguz et al., 2012).

2.2.10 Tools and techniques of Six Sigma

The Six Sigma methods have a considerable overlap with the quality engineering body of knowledge (Chiarini, 2011). Six Sigma originated as a quality focus for reducing process variation (Assarlind et al., 2012;), leading to near-zero breaches of specification limits, and thereby, near-zero defects (Corbett, 2011; Mayeleff et al., 2012; Montgomery, 2010; Oguz et al., 2012). The Six Sigma approach can be used to reduce variations in the product goal, to realign the process centre with the product goal, or both (Antony, 2010; Dumitrescu & Dumitrache, 2011).

As process variation creates some degree of defects, it is considered as waste from a Lean perspective (Mayeleff et al., 2012). Taguchi formulated a model which demonstrates the importance of uniformity, "working for less and less variation about the nominal value" (Deming, 1986). The Six Sigma strategy DMAIC is executed by means of improvement projects (Corbett, 2011; Goh, 2012). Projects are chosen based upon their relevant links to the organisational strategy and their bottom line contribution (Corbett, 2011). The Six Sigma methodology follows a meticulous project management framework consisting of five phases: define measure, analyse, improve, and control (DMAIC) (Corbett, 2011; Duarte et al., 2012). The "linear and sequential" DMAIC protocol (Gibbons et al., 2012), consisting of a systemic integration of tools and techniques (Goh, 2010), is the basis for the Six Sigma problem-solving methodology (Chiarini, 2011; Hoerl & Snee, 2010b). Such integration exemplifies that the "whole of the DMAIC deployment is larger than the sum of the parts" (Goh, 2010).

The DMAIC roadmap is an original collection of statistical and quality related tools and techniques which can be generally applied to any problem-solving effort (Hoerl & Snee, 2010b). The DMAIC roadmap is often described as being akin to the plan-do-check-act (PDCA) cycle of improvement, introduced by Walter Shewhart and further advanced by Edwards Deming (Duarte et al., 2012;).

2.2.11 Six Sigma Dominant Models

Six Sigma methodology over the years has evolved and has incorporated Lean tools and techniques (Gershon et al., 2011). Some researchers are of the opinion that Lean Six Sigma and Six Sigma are identical in every way (Duarte et al., 2012; Dumitrescu & Dumitrache, 2011). Snee (2010) applied the terms Six Sigma and Lean Six Sigma interchangeably, and stated that adding the term Lean is simply a recognition of the fact that Lean concepts have been added to the Six Sigma tool portfolio.

Most researchers are of the opinion that LSS is simply Six Sigma reformulated with Lean tools and phrases (Gershon et al., 2011; Hoerl & Snee, 2010a). Most LSS training offers black belt certificates based upon training that is not far from the traditional DMAIC-based Six Sigma curriculum (Chiarini, 2011). The essence of the LSS methodology is still underpinned by the Six Sigma DMAIC roadmap (Gershon et al., 2011). Lean tools and techniques are part of the American Society for Quality (ASQ) Six Sigma body of knowledge, further indicating the breadth of the implication that a major form of LSS identifies Lean as a subset of Six Sigma (Arnheiter, et al., 2010).

LSS is an evolution of Six Sigma, with Lean tools and techniques interwoven into the Six Sigma methodology (Gershon, 2011). However, Hoerl & Gardner (2010) stated that if LSS is considered simply as Six Sigma plus Lean tools (i.e. as an add-on rather than a fully integrated aspect) then it "is not a holistic business improvement system" (Hoerl & Gardner, 2010).

A Swedish firm incorporated a version of Lean into Six Sigma and applied components of Lean and Six Sigma with the purpose of enhancing their cohesive production system (Assarlind et al., 2012). The two methodologies employed by the firm have since become integrated into a single system (Salah et al., 2010). Within this unified system, the DMAIC framework is utilised for every form of improvement activity (Arnheiter, et al., 2010; Assarlind et al., 2012).

Montgomery (2010) argues that Lean initiatives can be executed via the DMAIC project management scheme. With regards to the Swedish firm, individuals qualified for black belts in both Six Sigma and Lean (Arnheiter, et al., 2010). The tools from both methodologies were selectively incorporated, depending upon the requirements of the respective projects (Assarlind et al., 2012; Hoerl & Gardner, 2010; Salah et al., 2010).

The Lean ideology represents the key foundation of the improvement model, as demonstrated by Toyota (Pepper & Spedding, 2010). In the pursuit of the Lean ideal state, obstacles, referred to as "hot spots", are encountered (Pepper & Spedding, 2010). Six Sigma is deployed within these hot spots "driving the system towards the desired future state" (Pepper & Spedding, 2010). There are some existing theories that explain Lean Six Sigma. For example, Pareto analysis reflects a theory for project prioritisation within the Six Sigma DMAIC framework (Hoerl & Snee, 2010b).

2.2.12 Benefits of Six Sigma

Kuhn (1996) developed a theory stating that a paradigm becomes obsolete at the moment a new paradigm is introduced that addresses unresolved issues that the old model is unable to resolve. On the other hand, the systems theory methods are orchestrated rather randomly, so as to ensure a synergistic outcome (Assarlind et al., 2012). The execution of Lean objectives without concern for the stability of the operations results in a worsened outcome, due to lack of consideration for the systems (Pepper & Spedding, 2010).

The systems theory might dictate that Six Sigma methodology be deployed in areas of instability, in order to achieve Lean deployment which requires a stable environment (Liker, 2004; Rother, 2010). Many researchers are of the opinion that methodologies such as LSS positively impact market competitiveness (Mayeleff et al., 2012). Hoerl and Snee (2010b) argue that LSS was based upon an improved theory, that it is more efficient than Six Sigma, and that more research should be carried out on the LSS theory (Hoerl & Snee, 2010b).

The Lean Six Sigma theory is described as follows: if important business metrics are represented as Y's, and all work is performed in processes, then these processes can be represented by the cause-and-effect equation $Y=f(X)$. The logic follows that it is important to pursue the knowledge that is obtained by solving the $Y=f(X)$ process equations, the essence of Six Sigma. Six Sigma is a framework for resolving $Y=f(X)$ and thereby increasing knowledge that is of supreme importance to the organisation.

A holistic system cannot be realised until the entire workforce embraces improvements project-by-project on a daily basis, leading to an improvement mentality or culture (Snee, 2010). The success of these efforts is due to the Toyota Kata philosophy (Rother, 2010).

Envisaging employees as strategic improvement assets is a cultural distinction between Lean with its Japanese roots and Six Sigma founded in America (Chiarini, 2011).

The original framework was MAIC, only to have the "define" phase integrated by General Electric (Hoerl & Snee, 2010b). The evolution of the framework will continue into the future as expected based on academic study (Hoerl & Snee, 2010a). As a result of these shared origins of the framework, it was foreseen that Lean and Six Sigma methodologies would be merged (Assarlind et al., 2012).

Some firms have "adopted LSS after a lengthy journey with other improvement programmes basis for an approach that would give greater benefits and build on the earlier work" (Corbett, 2011). One model of Lean Six Sigma is Six Sigma with Lean tools added, as an evolutionary replacement for Six Sigma, but it is not a replacement for Lean as defined and practised by Toyota Production Systems. The Six Sigma methodology's scope has been elevated by enhancing process flow, and increasing the toolbox; its effectiveness has been heightened by incorporating Lean into its own body of knowledge (Goh, 2012; Hoerl & Gardner, 2010; Hoerl & Snee, 2010b). Conversely, there is less evidence that Lean practitioners seek to absorb Six Sigma into the Lean body of knowledge, except as it is already present in the practice executed by trained engineers (Watson and deYong, 2010).

2.2.13 Six Sigma Adoption

It is widely posited that Lean and Six Sigma complement one another (Assarlind et al., 2012; Salah et al., 2010). Six Sigma's focus on defects and Lean's emphasis on waste are parallel approaches indicating similar objectives (Montgomery, 2010). Waste elimination inevitably results in variation reduction (Goh, 2010).

Many researchers have agreed that Lean and Six Sigma can be combined, due to the shortcomings inherent in each (Antony, 2011; Corbett, 2011; Oguz et al., 2012); an optimally effective merger should be derived (Assarlind, et al., 2012). The Lean Six Sigma hybrid yields synergistic benefits compared to the parallel deployment of each individual approach (Oguz et al., 2012; Salah et al., 2010). An issue with the parallel deployment of Lean and Six Sigma results in clashing for common resources (Liker, 2004; Salah et al., 2010). A benefit is the emphasis on speed by the Lean methodology and on capability by Six Sigma (Duarte et al., 2012).

Succinctly, Lean and Six Sigma together address both efficiency and effectiveness (Antony, 2011; Duarte et al., 2012; Dumitrescu & Dumitrache, 2011). The DMAIC framework belonging to Six Sigma affords an improvement deployment structure that is often lacking in Lean approaches (Ngo, 2010). Moreover, control and improvement of processes often require a higher level of statistical analysis that is inherent in Six Sigma but is often missing from many Lean deployments (Assarlind *et al*., 2012; Pepper & Spedding, 2010). On the other hand, Six Sigma is regarded as not effectively addressing process flow (Antony, 2010), a key principle of Lean (Womack & Jones, 1996).

A fundamental principle of Lean is the requirement for stability (Liker, 2004; Rother, 2010). Complex stability is best rooted out via Six Sigma (Antony, 2011; Salah et al., 2010). “Six Sigma complements Lean philosophy in as much as providing the tools and know-how to tackle specific problems identified along the Lean journey” (Pepper & Spedding, 2010). In a case study of an engineering company’s reaction processes, Lean and Six Sigma synergy proves that Six Sigma projects often suffer the effects of entropy during the control phase (Assarlind et al., 2012). The Lean practice of continuous improvement during the Six Sigma control phase can counteract such a decrease in performance post-Six Sigma project closure (Assarlind et al., 2012). Such integration “facilitates the transfer of Six Sigma project results to daily operations for sustained improvements” (Assarlind et al., 2012).

2.2.14 Enablers of Six Sigma

Firms demand improvement and both Lean and Six Sigma are needed to effectively solve the problems encountered (Snee, 2010). The merger of Lean and Six Sigma “provides a more integrated, coherent and holistic approach to continuous improvement” (Pepper & Spedding, 2010). As a corollary to the Juran Trilogy (Bisgaard, 2008), Hoerl and Snee (2010a) argued that a holistic continuous improvement requires process design (quality planning), process control (quality control) and process improvement (quality improvement).

Process design may be optimised with the Six Sigma variant design for Six Sigma (DFSS). The processes that deviate from the standard are brought back within control via every day problem solving. The characteristics of the Lean philosophy and process improvement are generally addressed by both Six Sigma and Lean (Hoerl & Snee, 2010a). Some problems originate within the processes (the domain of Six Sigma) while other problems are confined to the space between processes, the primary focus of Lean (Antony, 2011; Liker, 2004; Snee, 2010). Problems within the process can negatively impact the flow of material, and vice-versa; a solution would be a holistic approach deploying both Lean and Six Sigma concepts concurrently in order to address the underlying interactions at play (Snee, 2010).

The above demonstrates the need for a holistic system of process improvement (Snee, 2010). The Joiner Triangle (Joiner, 1994) is a model which depicts quality management as being equally balanced between three major concepts: quality, scientific approach, and "all one team" (Pepper & Spedding, 2010). The Six Sigma methodology has skewed quality management in the direction of the scientific approach corner of the triangle model, discounting the "all one team" people aspect (Pepper & Spedding, 2010).

Cultural issues may be diminished by the integration of leadership and coaching (Antony, 2011; Rother, 2010), it would in effect hinder the holistic philosophy of the improvement methodology (Pepper & Spedding, 2010). "A state of equilibrium needs to be achieved" between the integrated elements (Pepper & Spedding, 2010; Salah et al., 2010). A holistic answer "is to embed a coherent systems philosophy that integrates culture with a scientific approach through a unified hard/soft systems thinking philosophy" (Pepper & Spedding, 2010). The hard systems being referred to here are the technical aspects of the Six Sigma methodology and the soft systems comprise the cultural emphasis of Lean.

Liker (2004) stated that Six Sigma and Lean are tool kits that are important and necessary, but both still lacking the cultural aspect that distinguishes the Toyota Production System (TPS) as a holistic management philosophy (Liker, 2004). It is often argued that organisations that apply Lean suffer from the lack of technical analysis which is afforded by Six Sigma (Antony, 2011; Pepper & Spedding, 2010).

However, mature Lean organisations in Japan integrate "production engineers" into their continuous improvement activities, bringing to bear the same quantitative skills that are part of Six Sigma (Watson and deYong, 2011). Another view point on a holistic continuous improvement system entails the recognition that Six Sigma facilitates the resolution of complex problems, often requiring statistical analysis conducted by a few specialists, while concurrently deploying the remainder of the organisational human resources to engage in daily continuous improvement on a smaller yet more frequent scale (Corbett, 2011; Antony, 2011).

2.2.15 Links to other disciplines

Montgomery (2010) "advocates a deployment of Six Sigma combined with DFSS and Lean as an ideal systems framework to bring about Deming's philosophy of continuous improvement". A number of researchers recommend that a holistic model of Lean Six Sigma needs to be defined (Ngo, 2010).

A contribution to this priority is to identify and study organisations that are successful practitioners of LSS (Akbulut-Bailey et al., 2012; Salah et al., 2010). There are many versions of LSS, but it may be too late to rely on a unified model (Marsh, Perera, Lanarolle, & Ratnayake, 2011). The Japanese influence on successful integrators of Lean Six Sigma remains undefined (Chiarini, 2011).

2.3 Lean Six Sigma

The characterisation of Lean Six Sigma does not fit a neat definition, even amongst employees within this case study firm (Assarlind et al., 2012). LSS, as deployed, is versatile and adaptable, contingent upon the requirements of the activity (Assarlind et al., 2012). There is some contention over whether this version of Lean Six Sigma is a true assimilation or a parallel deployment of Lean and Six Sigma (Assarlind et al., 2012). These varying views are not necessarily a contradiction but instead are a "matter of perspectives" (Assarlind *et al.*, 2012).

Many firms' improvement teams consider Lean to be the blueprint for routine continuous improvement, while Six Sigma is reserved for major obstacles requiring a more sophisticated approach (Assarlind *et al.*, 2012). In a case where a larger project is assigned to a black belt, the Six Sigma approach is used, readily incorporating Lean tools and ideas (Assarlind *et al.*, 2012); moreover, the black belt improvement professional is afforded this level of discretion

(Assarlind *et al.*, 2012). While the DMAIC framework is used for the improvement team's daily improvements, the influence of Lean is clearly apparent (Assarlind *et al.*, 2012).

The Lean philosophy can dictate project priorities, often subsequent to value stream mapping exercises. Assarlind et al. (2012) contended that a single universal method cannot be equally effective for shop floor level improvement projects and complex projects requiring sophisticated analytics, which rely upon divergent tools and techniques, and concluded that the advantages of Lean and Six Sigma can be realised without the adherence to a blended Lean Six Sigma model prescription.

Despite this declaration of a Lean Six Sigma integration, much of this study focused on the lean aspects of Lean Six Sigma such as one piece flow, standard work, Kanban, and jidoka; there was very little mention of Six Sigma details. This reflects the likelihood that at Johnson Technologies Inc., Lean Six Sigma takes a Lean dominant form. In the case of companies observed by Corbett (2011) "there was little evidence of the dominance of one component [Lean or Six Sigma] over the other… the choice of tools to be used in the identified projects was left to the teams" which points to the fact that they regarded Lean Six Sigma (LSS) as being more akin to a tool set than a holistic integration.

The improvement practitioners determined which tools to execute, depending upon the nature and need of the project (Corbett, 2011). Pepper and Spedding (2010) developed a LSS integration model in which Lean is the dominant methodology and Six Sigma is used in a subordinate role. This model constitutes a comprehensive management approach addressing all manner of business process improvement (Pepper & Spedding, 2010).

The "define" phase of DMAIC consists of designating the process that warrants transformation (Akbulut-Bailey et al., 2012) and The "measure" phase amounts to depicting the process in a visual map and measuring the current state of the process which establishes a baseline against which improvement can be measured (Akbulut-Bailey et al., 2012; Oguz et al., 2012).

The measurement device by which the process is measured is also validated. In the "analyse" phase, the potential causes for poor performance, as designated in the $Y=f(X)$ equation, are derived. Pertinent data are collected and analysed, statistically and otherwise, with the intent of determining the strength of the hypothesised *Y=f(X)* relationships, thereby exacting the root causes of the process problem (Oguz et al., 2012). The "improve" phase entails the actual transformation of the process, so as to resolve a problem and/or improve process performance, based upon the findings of the "analyse" phase (Akbulut-Bailey *et al*., 2012; Oguz et al., 2012).

In the "control" phase the sustainment of the improvements installed in the improve phase are assured by means of documentation, including process controlling and monitoring plans (Akbulut-Bailey et al., 2012; Oguz et al., 2012). The DMAIC disposition of projects is confirmed stage-by-stage with intervening tollgates (Chiarini, 2011). The appeal of Six Sigma lies in the resultant cultural change more so than the application of statistical tools (Chiarini, 2011; Goh, 2012).

To ensure Six Sigma success, participation is expected from all parts of the organisation, particularly from upper management (Dumitrescu & Dumitrache, 2011; Goh, 2010). The Six Sigma methodology is deployed by teams, under the direction of management and led by skilled professionals (Chiarini, 2011; Shah *et al.*, 2008). However, a key role in the structure is the project leader, in the form of a highly trained Six Sigma expert called a black belt (Chiarini, 2011; Corbett, 2011). The other roles in the Six Sigma structure are champion (project owner/ supervisor), master black belt (Six Sigma consultant), and green belt (lesser trained project leaders) (Goh, 2010). The philosophy of holding the Six Sigma leadership responsible for quality improvements abandons the concept that quality is the responsibility of everybody, which can regress into quality being the responsibility of nobody (Goh, 2010).

Zhang et al. (2012) adopted Lean Six Sigma and discovered, in a total of 116 relevant research publications, that the main area of focus for implementing Lean Six Sigma has been process improvement (Figure 2.1). In contrast, as evident in Figure 2.1, the area of risk management has been paid the least attention in the literature.

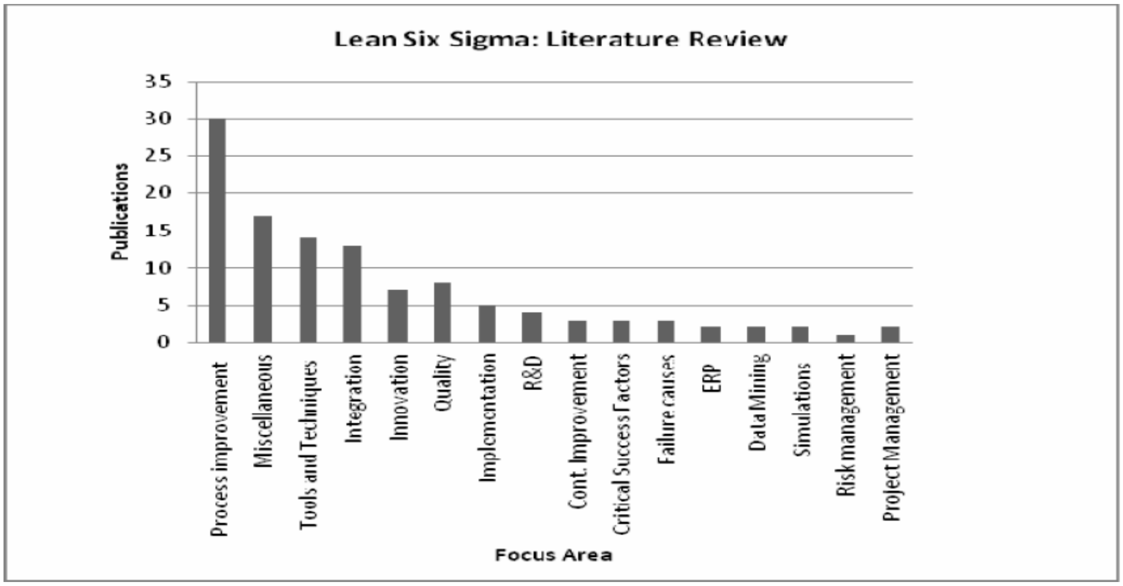


Figure 2-1 Focus area of implementation of LSS, sourced from Zhang et al., 2012

Additionally, Zhang et al. (2012) found that there is a difference in Lean Six Sigma research for developed and developing countries. The USA is considered the leader in Lean Six Sigma related research, followed by the UK. Figure 2.2 below shows that only a few Middle Eastern countries have contributed any research in this area. Certainly, this issue, together with the above-stated lack of implementation in risk management, have inspired this research to investigate the implementation of Lean Six Sigma in a health risk management-related area, namely occupational health and safety management in the Saudi media industry. Therefore, the next sections discuss in more detail the philosophy of Lean Six Sigma methodology, followed by how the occupational health and safety management system could be combined with a quality management system such as Lean Six Sigma.

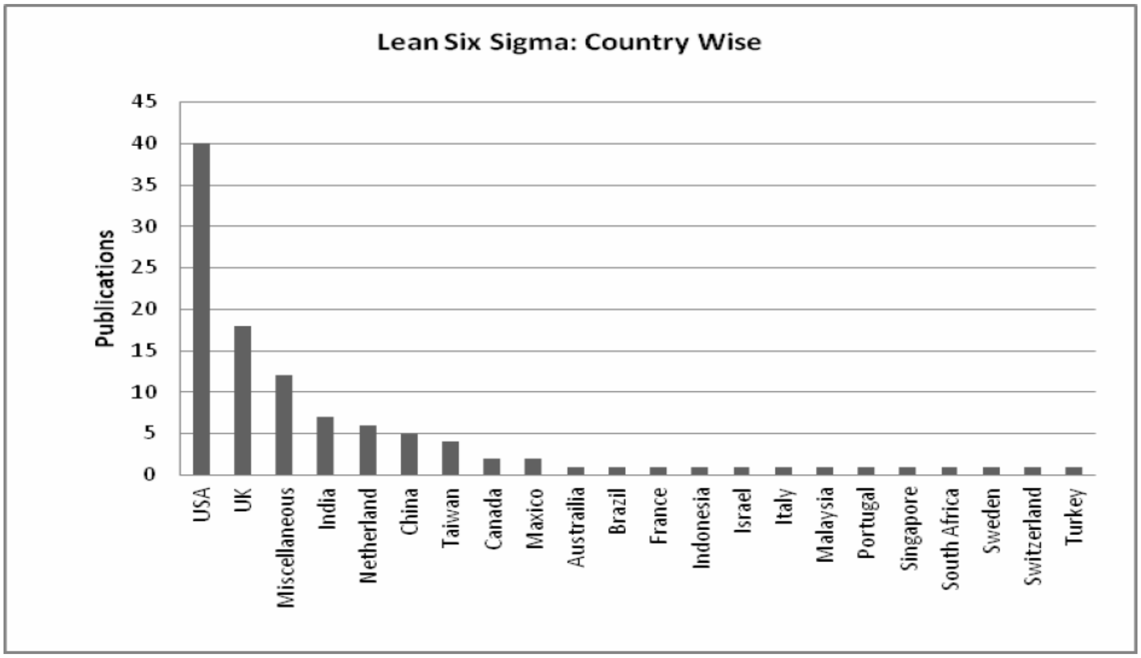


Figure 2-2 Differences in LSS research in developed and developing countries, sourced from Zhang et al., 2012

2.4 Occupational Health and Safety Management System

Occupational Health and Safety Management Systems (OHSMS) have been defined by Gallagher (2000) as "…a combination of the planning and review, the management organisational arrangements, the consultative arrangements, and the specific programme elements that work together in an integrated way to improve health and safety performance". OHSMS implementation has four primary components.

These are safety policies (policy statements, organisational structure, procedures), safety risk management (hazard identification, risk assessment, risk mitigation and tracking), safety assurances (internal audits, external audits, corrective action), and safety promotions (culture, training, communication) (Ludwig, 2007). Over the past decade, OHSMS has been used by many industries as a proactive process to avoid injuries and loss of life, and reduce several costs. Safety regulations have been reactive and prescriptive because they generally occur after a significant safety failure (Ludwig, 2007). However, today most industries such as aviation, petroleum, nuclear, railroad, marine, and chemical have complex production processes. Prescriptive regulations are not an effective form of improvement, so these industries have replaced the prescriptive approach with OHSMS processes (Ludwig, 2007; Alli, 2008). Management leadership and employee participation have been found to be the most important components in the success of OHSMS (Manuele, 2008). The common aim of the organisations OSHA, ANSI, VPP, NIOSH, BSI, ISO etc. is to assist private and federal agencies to prevent work-related accidents and illnesses in the workplace and implement effective health and safety management systems.

ISO 9001 and ISO 14001 management system standards are not directly related to OHS, however, ISO 9001 supports organisations in implementation of quality management systems, and ISO 14001 supports the implementation of environmental management systems. These standards are models for continual improvement, satisfying internal and external customers and other stakeholders. Therefore, the goal of ISO 9001 and ISO 14001 is to improve product quality and the work environment.

These can be implemented by companies easily, alongside other safety-based standards. The best OHSMS involves every level of the organisation, creates a safety culture that decreases accidents and injuries and improves the bottom line for managers ("Safety & Health Management,"). The other benefits are a reduction in the direct and indirect costs of accidents, avoiding incident investigation costs, and increasing employee morale and productivity, establishing a marketable safety record, compliance with legal responsibilities for safety, more efficient maintenance scheduling, and continuous improvement of operational processes (Ludwig, 2007). OHSMS are used in many industries as management systems have been implemented to prevent accident costs and loss of life.

OHSMSs are common not only in the construction industry ("fall protection"), but also in oil and gas industries where employees generally work on elevated platforms (U.S. Department of Labor, OSHA, n.d.). Employees work long hours outdoors or underground, lifting heavy objects, wearing a great deal of Personal Protection Equipment (PPE) as well as working at height. These conditions increase the risk of accidents (Krishnamurthy, 2010).

While performing a risk assessment to define hazards in a workplace, the distance of the working platform from the floor, work duration, weather conditions, physical limitations, access and entry points, whether the workplace requires working at height or not, emergency actions plans, and the workers' abilities and training should be considered (Chief Executive's Department, Health, Safety & Wellbeing Team Human Resources, 2006). Personal protection equipment (PPE) can be used to reduce injuries which result from falling from heights.

Guards rails, catch netting, barriers (Krishnamurthy, 2010), rail systems and retractable lifeline systems are collective controls; shock absorbers and various types of lanyards (Salentine, 2011) are examples of PPE. In addition to these controls, equipment cradles, mobile towers and ladders are used to make the operations easy and safe (Chief Executive's Department, Health, Safety & Wellbeing Team Human Resources, 2006). According to Lewis and Payant (2003), an emergency is "an unforeseen combination of circumstances or the resulting state that calls for immediate action". High winds, fires, explosions, bomb threats, hazardous material spills, toxic gas releases (U.S. Department of Labor, OSHA, 2001) and radiological accidents are examples of emergencies in workplaces.

Management support and involvement of all the workers are basic components of effective emergency preparedness. Primarily, the potential emergency situations must be defined in the facility and then the emergency action plans can be prepared. OSHA standard 29 CFR 1910.38(a) requires these plans to identify the employers' and employees' actions during emergencies (U.S. Department of Labor, OSHA. n.d.). Emergency action plans include reporting emergencies, evacuation, rescue and medical duty procedures (U.S. Department of Labor, OSHA, 2004), escape procedures and route assignment such as meeting points, exit routes, floor plans and workplace maps (U.S. Department of Labor, OSHA, 2001).

The emergency action plan also includes the names and contact details of people both within and outside the company (U.S. Department of Labor, OSHA, 2001) who should be contacted in emergency situations in order to inform them of the situation or to request assistance. The Emergency Response Team plays a vital role in protecting people and reducing damage to the facilities (Ray, 2006) in the event of an emergency situation (U.S. Department of Labor, OSHA. n.d.). Such teams are trained for each possible emergency situation (U.S. Department of Labor, OSHA, 2004). The training may be related to the team members' roles and responsibilities (U.S. Department of Labor, OSHA, 2001), emergency response and shutdown procedures, use of different kinds of fire extinguishers and other emergency equipment, chemical spill controls, search and emergency rescue, hazardous materials emergency response, first-aid, or blood-borne pathogens (U.S. Department of Labor, OSHA, 2004). After completion of the emergency action plan and training of the employees, drills based on the emergency plan keep everybody prepared.

The company can obtain support from outside resources such as fire or police departments. Drills of this nature give companies a chance to evaluate their action plans' effectiveness and to improve them. As a conclusion, establishing emergency action plans, training workers, providing necessary PPE and engaging in organised response operations are the key elements of successful emergency preparedness (Lewis & Payant, 2003).

2.4.1 Occupational Health and Safety in the BBC

The health and safety of all employees working at BBC productions, including management, crew, sponsors and the audience, is of high priority to the BBC. The BBC conducted a risk assessment procedure on every channel and production to identify any potential hazards. The company follows a safety management system to prevent accidents from happening (Broadcastnow, 2011; Funtowicz, 2007)

As a result of health and safety measures taken by the channel, there was a huge decline in the number of falls, slips and trip accidents that were reported in the BBC studios in 2009, compared with the previous year (The BBC Executive's Review and Assessment, 2009). The BBC exists to enrich people's lives with great programmes and services that inform, educate and entertain. Their vision is to be the most creative and trusted organisation in the world (HSE, 2013; BBC, 2015).

Safety and security is an integral part of the BBC's vision. One of the main objectives of the BBC is to secure a safe working environment for all employees; they achieve this with effective security, the implementation of an occupational risk management system that meets the requirements of the BBC and the UK's Health and Safety Executive (HSE), by setting safety objectives and targets, constantly reviewing the management system and policy to ensure their suitability, adequacy and effectiveness, providing sufficient security information, instruction and training to enable all staff to carry out their jobs adequately, and finally with effective cooperation with third parties with regard to security expectations (BBC, 2015).

2.4.2 On location and on set:

Production filming BBC studios, including private company productions and on location productions, conduct health and safety assessments. BBC assigns a health and safety team member to support every production, whether private or on location (BBC Security on Location, 2015).

Falls, slips and trip accidents which occurred in productions reported in the year 2009 were classified as high risk. The company probed their root causes in order to take correct measures for prevention. One quarter of the production accidents reported in 2009 were caused by falls, slips and trips. The BBC has taken many preventive measures in order to reduce the accident percentage, one of which is a routine inspection for all types of trip hazards (The BBC Executive's Review and Assessment, 2009).

2.4.3 Occupational Health and Safety in SBC

Occupational Health and Safety Management Systems (OSHMS) are an integral part of the SBC media organisation. The importance of OSH systems stems from the need to decrease the number of employee injuries occurring during work hours, and the need to adhere to the Saudi Arabian Labour Law Part 8 regulations. The Labour Law Part 8 of Saudi Arabia was first published in 2005. The Labour Law defines all aspects of relations between the employer and his employees from organisation of recruitment, passing through training and work relations, to punishments. The eighth part of this Labour Law is simply the national Law of Occupational Health and Safety in Saudi Arabia (Saudi Arabia's Ministry of Labour, 2005). The Law defined all the rights and responsibilities of workers in the field of occupational health and safety. This law encompasses four sections, the first of which is Protection against Occupational Hazards. This section presents all the services that the employer should provide to protect his employees and visitors from occupational hazards. This includes:

- Providing a healthy and safe working environment.

- Taking all the necessary precautions to protect employees from hazards, diseases, the machinery in use, and fires.
- The employer is responsible for all accidents that may affect any person entering the workplace other than his employees and should provide remedy and compensation for them.

The SBC implements policies and procedures in order to adhere to both the Labour law and safety regulations. These regulations aim to protect all employees from occupational hazards which are embedded in the ILO regulations of 2001 and the Health and Safety Executive (HSE) regulations, which are similar to BBC regulations but contain several differences such as employee’s culture and political roles. The regulations are also related to an organisation's OSH systems. The OSH management systems in the organisation have five main sections. These sections are Policy, Organising, Planning and Implementation, Evaluation and Actions for Improvement (ILO, 2001). The company adopted OSH standards and have incorporated them into their management system. ILO-OSH 2001 regulations were issued by the International Labour Organisation in 2001 for the purpose of protecting the workers from occupational hazards and eliminating or controlling work- related hazards, ill health, diseases, incidents and deaths. Also, a five-step risk assessment standard was designed by the Health and Safety Executive (HSE) in 2006 to help organisations to implement effective and flexible risk assessments (Appendix C). This standard is internationally accepted and is recommended by ILO (ILO, 2011).

According to HSE, five steps should be followed to implement risk assessments:

1) Identify the hazards.
2) Decide who might be harmed and how.
3) Evaluate the risks and decide on precautions.
4) Record your findings and implement them.
5) Review your assessment and update if necessary.

The author’s work has helped the SBC media organisation to meet both the Labour Law Part 8 of Saudi Arabia, and ILO-OSH 2001 regulations, utilising the integrated approach of Lean Six Sigma tools.

2.5 Lean Six Sigma and Occupational Health and Safety

According to Nielsen (2000), integrating the Lean concept and OSH is not an easy task since “Lean focuses on minimising waste in a system where as Safety focuses on minimising risk in a system. Therefore, using either one to optimise the system results in a less efficient solution for the overall system – less waste but with higher risk, or lower risk with higher waste. (Main et al., 2008). Therefore, the reviewed literature did not offer a roadmap outline for implementing Lean Six Sigma in service or non-manufacturing organisations.

This research study applies Six Sigma tools such as DMAIC, Cause-and-Effect/Fishbone Diagrams, Failure Mode and Effect Analysis (FMEA), and Lean tools such as Value Stream Mapping to analyse risks associated with hazards (such as fire, falls and electricity). The research will provide a roadmap for implementing Lean Six Sigma in the media industry in Saudi Arabia.

2.6 Ishikawa diagram

An Ishikawa diagram or cause-and-effect diagram (sometimes called a "fishbone" diagram) is used to graphically display the relationship between problem solving and causes affecting its appearance. The technique was developed Dr. Kaoru Ishikawa in the 1960s (Enarsson, 1998; Kelley, 2000). The fishbone diagram is used in conjunction with the method of brainstorming, which allows the participants to quickly decide on key categories of causes of the problems. The Ishikawa Diagram provides an opportunity to identify key process parameters that affect the characteristics of the products, to establish the causes of process problems, or factors that influence the occurrence of the defect in the product. In the case where the above solution involves a team of specialists, a cause-and-effect diagram helps the group to reach a common understanding of the problem. Also, the Ishikawa diagram can analyse any data, information or knowledge and determine the causes of problem using deduction from decisions, thereby reducing the area of decision (Survey Monkey, 2010).

The causes of problems are distributed into key categories, as follows: people, working methods (actions), machinery, materials, control and environment. The number of categories for plotting can be reduced depending on the problem. A chart with the maximum number of categories is a diagram type 6M. An Ishikawa diagram can be constructed as follows:

a) Identify potential or existing problems to solve. Problem formulation is placed in a rectangle on the right side of the paper. A straight horizontal line is then drawn from the rectangle to the left (Sunder, 2013).

b) The edges of the sheet on the left-hand side identify the key categories of reasons that cause the problem under study. The number of categories may vary depending on the problem. Typically, there are five or six categories from the list above (people, work methods, mechanisms, material control, and environment). This ensures a comprehensive analysis of the studied problem, regardless of its category or severity (Ishikawa, 1986).

c) The categories of reasons are connected to the centre line with slanted lines which are the main "branches" of the Ishikawa diagram.

d) The causes of the problems are identified in the "brainstorming"; they are distributed in the categories specified and shown on the diagram as "branches", adjacent to the main "branches" (Sunder, 2013). The maximum useful branching depth is normally four levels, because if the diagram becomes more complicated, it will also be more difficult to comprehend and apply (Pande & Holpp, 2001).

e) Each cause is examined by asking the question "Why did this happen?" The results are recorded in the form of "branches" of the next lower order. This process of detailing the reasons continues until the "root" cause is found.

f) A Pareto diagram is used to identify the most significant and important factors influencing the investigated problem. This leads to further work being carried out, and determining corrective or preventive actions.

2.6.1 Fishbone Analysis

Fishbone analysis, based on the Ishikawa diagram which is named after its inventor, is a valuable tool in solving problems (Pearson, 2005). The diagram derives its name from its resemblance to the spine and ribs of a fish and it provides a useful template for organising potential causes of problems during brainstorming. Fishbone analysis essentially consists of gathering a group of knowledgeable people together to generate ideas about possible causes of the problem; these are then organised by type, as the first step to solving the problem (Stanleigh, 2006). It follows these basic steps:

- Define the problem to be solved in one short sentence. The sentence should be simple and to the point and should address the root (the main) cause of the problem. For example, the statement of the problem, such as "Too many reject parts" is too general. The statement "puncher number 3 produces too many reject parts "is more specific and more useful.

- Gather together a group of people from your organisation who may be aware of the problem and its possible causes and possible solutions. This group should be as diverse as possible and include technicians, shop staff and management. If possible the meeting should be in a primary location such as a conference hall (Stanleigh, 2006).

- On a large sheet of paper placed landscape, draw a central horizontal line. Make three "ribs", starting from the horizontal line and radiating upwards at an angle and then make three more radiating downwards at an angle. Each of these angled lines may have further smaller horizontal lines leading from them. The graduated drawing should take up most of the paper and resemble a fishbone.

- Label the six ribs with the "Six Ms". These are the six main causes of most problems within organisations: machines (hardware issues such as faults); labour (employee issues such as lack of training); mother nature (environmental problems, such as high humidity); material (issues such as poor quality of raw ingredients); measurement (issues such as incorrect weighing of chemicals); and methods (such as incorrect or outdated operating procedures and guidelines). Thus, the first rib is labelled as "machine", the second "labour", and so on.

- The first rib represents the possible causes of problems (obtained from the group brainstorming) that fall into this category. People can just say whatever comes to mind without having to worry about whether a particular cause is likely or not. For each sentence, draw a new line, emanating from the edge and write a sentence on this line. In the example of reject parts of the die press, the possible causes listed in the machine may include a "misalignment" and "tool wear blow" (Rickards & Moger, 2000).

- The process continues until completed, when all the potential causes have been entered onto the diagram. Then these reasons can be explored, categorised into groups, and those that appear unlikely can be eliminated from the preliminary investigation. They should not be completely erased from the diagram however, so that in the future they can could be returned to if the problem is not resolved during the preliminary investigation.
- Write down a list of the reasons that remain. These are the possible causes of the problem that your group will focus time and energy on to solve the problem (Smith, 2001).
- Photograph and record the completed Fishbone diagrams. At the end of the meeting, summarise your findings in a report. Fishbone analysis is then complete and problem-solving will enter the next stage of the development of methods to check which of the identified possible causes is true.

Fishbone analysis is used more and more to improve safety and quality, and to minimise contradicting events (Pearson, 2005) because it is a useful tool for solving problems, and helps to identify all the possible causes of a problem, including the hidden ones (Hughes et al., 2009).

2.7 Failure Mode and Effects Analysis (FMEA)

A FMEA is a proactive risk assessment of a process that aids in identifying how a process can fail and how those failures can lead to defects. FMEA is conducted based on experience with a process in which the failure mode is analysed and its impact on the system highlighted. FMEA allows the project team to prioritise the risks of the project and develop action plans to reduce those risks. Specifically, FMEA focuses on the types of errors that could happen within the prescription dispensing process. The project team assess the potential failures (types of errors that could occur) and score them based on a rating system to give each one a risk priority number (RPN). The rating system is based on three indicators; Occurrence, Severity, and Detection. The RPN is derived from multiplying each indicator together (Savolainen & Haikonen, 2007).

The higher the RPN value, the greater the concern for a potential failure; this indicates a process that requires action. Once the RPN values are calculated, recommended actions are determined along with responsibility and dates for implementation. Essentially, the action plan should try to eliminate the failure mode. At the very least, the action should minimise the severity of the failure, reduce the occurrence of the failure and improve the detectability of any fault (Silverman, 1994).

A case study of FMEA in an outpatient pharmacy listed all the potential failures or opportunities for errors to occur. From all the potential failures (errors) that could occur, those with the highest RPN were associated with the data entry function in the prescription dispensing process. The three highest ranked failure modes were related to typing incorrect information into the computer system, potentially leading to severe implications if the error reached the project. Completing the FMEA further enforced the need to improve the data entry process step (Schroeder, 2008).

Bouti and Kadi (1994) applied the FMEA method by identifying failures of a system, their failure modes, the causes of the failure modes, and finally the effects of each potential failure mode on the system, and then issuing appropriate corrective actions.

Teoh and Case (2004) discovered that FMEA was a quality improvement and risk assessment tool, frequently applied in industry and could be used for general applications. Teoh and Case proposed that FMEA should be used in the early design stage in order to minimise the risks and costs of failures. Teoh and Case developed a prototype to assess the proposed method with the assistance of case studies.

2.8 Pareto principle

The Pareto principle is a recognised rule of thumb which states that 80% of the target can be achieved in 20% of the time assigned (Wu et al., n. d.; Iqbal et al., 2009). It has been generally applied in many industries (Koch, 1998). The 80/20 rule of thumb was created in the late 19th century by economist Vilfredo Pareto during a study on the distribution of wealth between the different layers of the population in England at the time. Pareto came to a stunning discovery when he discovered that 20% of the population of England owned 80% of the country's wealth (Shah, 2008).

Pareto also noted that 10% of the population owned 65% of the wealth, with between 5% and 50% of the population owning the material resources. Investigating the distribution of wealth among the population of England and other countries in different historical periods, Pareto reported similar findings. Thus the 80-20 rule was proposed, but unfortunately the scientist could not explain it and it was left unsupported until 1949, when a professor at Harvard University, George K. Zipf, again drew attention to the pattern (Senapati, 2004).

Zipf came to the conclusion that around 20-30% of effort results in 70-80% of the maximum impact that you could achieve. Thus, Zipf reinvented the Pareto principle, showing the basics of the self-organisation of all resources. Around the same time, Joseph Juran, exploring statistics of the distribution of marriage at work, reiterated the principle of 80-20, and published a book in which the law a "few that are crucial" was formed. Juran called for the mass introduction of this principle in different spheres of production, in order to eliminate the marriage and to improve the quality of manufactured goods. Juran argued that Pareto's principle of non-uniform distribution can apply not only to the sphere of production, but can also serve as a statistical approach to the study of the distribution of crimes, accidents, and other processes. Unfortunately, the US refused to accept the business ideas of Juran, although he found a grateful audience in Japan (Setijono & Dahlgaard, 2008).

As a result, in 1953, after reading a series of lectures in Japan, Joseph Juran stayed there and began collaborating with several major Japanese corporations. In the 1970s, he returned to his homeland, where industrialists were "ripe" for the implementation of his ideas. Furthermore, Japanese production had become a serious competitive threat for the United

States. In both countries, Juran headed a real industrial revolution based on the Pareto principle (Ranch, 2006).

A well-known IT giant, IBM, has actively adopted the first law of Pareto in marketing. In 1963, experts from IBM noticed that 80% of the time spent on computers accounted for 20% of the operations carried out on computers. Immediately it was decided to find that 20% that were used the most, and to make them as functional and comfortable as possible for the user. As a result, experts managed to create machines that were faster than similar devices of their competitors (Raja, 2006).

The Pareto principle applied to trade implies that huge business resources are spent on inefficient maintenance in terms of profits of goods and labour. Too much attention is paid to customers who account for only a small percentage of the income. Thus, there is a logical conclusion that focusing on the most effective areas will increase the profit of the company. In order to optimise your business, you need to transform it into an effective operation with the most productive employees who will be engaged in the sale of the most popular goods or services. It is vital to keep the customers, as the business does not want to lose a single one (Raisinghani et al., 2005).

The Pareto rule states that only 20% of customers give you 80% of the profits, while the remainder do not bring in much revenue. In order to do maximise profit, you must make every effort to work with high-potential clients and maintain contact with the other 80% in order to unify, and to reduce the time and cost for the company. This is the role of the leader in the management of the company (Proudlove et al., 2008).

At first, all of this may seem quite complex. Many managers and owners of companies with a large production capacity find it difficult to give up 80% of the activity in one day. However, radical changes would entail an incredible growth in profit and efficiency. In general, it can be concluded that it is not always necessary to strive to achieve 100%. Energy and resources spent on achievement should cover the possible benefits. In most cases it is sufficient to limit effort to 80%, while spending little money to achieve the result (Rai et al., 2009).

2.9 Bayesian belief networks (BBN)

Bayesian networks are probabilistic graphic models and they illustrate causal relations between variables in statistical information modelling. Bayesian networks can be combined organically empirical frequency of occurrence of different variables, subjective assessments of "expectations" and theoretical understanding of the mathematical probabilities of various consequences of a priori information (Powell, 1996). In another words, they draw conclusions about the likelihood of occurrence of certain events (Li, Y., 2009).

This is an important practical advantage of Bayesian networks and distinguishes them from other methods of information modelling. Observable events can rarely be described as a direct result of strictly determined reasons and widely used probabilistic descriptions of phenomena. There are several justifications and unrecoverable errors in the process of experimentation and observation, and it is impossible to provide a complete description of the structural complexity of the system being studied, and there is always uncertainty due to the finite volume of observations (Pheng, 2004).

There are certain probabilistic modelling complexities, which (apart from purely theoretical problems) can be divided into two groups:

- Technical (computational complexity, "combinatorial explosion", etc.);
- Ideological (the presence of uncertainty, complexity in formulating the problem in terms of probabilities, the lack of statistical material).

To illustrate one of the "ideological" complexities, consider a simple example from the field of probabilistic forecasting. The probability of a positive outcome is predicted in each of the three following situations:

- A noble lady claims that she can distinguish, purely from taste, whether the tea has been poured into the cream, or vice versa. She managed to do so 10 times during the ball.
- A gambler claims that he can predict whether a coin (which you give him) will fall heads or tails. He had won the bet already 10 times that evening, and never lost!

- An expert in classical music declares that he is able to discern the creation of Hayden and Mozart with only one page of the score. An outcome of 10 times was achieved in the music library.

The amazing feature of all three cases is the identical experimental evidence for these statements. Each case verified an outcome 10 times. However, the abilities will treat a lady, very sceptical statements perceive the good player, and quite naturally agree with the arguments of music experts (Paladino, 2007).

The subjective assessment of the likelihood of these three situations is quite different. They deal with recurring events which are very difficult to combine with the provisions of the classic theory of probability. They are particularly difficult to obtain written in clear computer language. The other ideological difficulty arises in the practical necessity of probabilistic forecasting of events, to which classical concepts of statistical reproducibility are not quite applicable. Imagine a series of experiments with the throwing of a dice made from sugar, on a wet surface of the table. The probabilities of the outcomes of subsequent tests depend on the relative frequency of outcomes of previous tests, with the system under study undergoing irreversible changes each time as a result of each experiment (Pantano et al., 2006).

This property is adopted by many biological and social systems, which makes the probabilistic modelling of classical methods extremely problematic. Part of the problem is solved in probabilistic Bayesian networks, which are a graphic model of causal relations between random variables. Bayesian networks can combine organically empirical frequency of occurrence of different variables, subjective assessments of "expectations" and theoretical understanding of the mathematical probabilities of various consequences of a priori information. This is an important practical advantage of Bayesian networks and distinguishes them from other methods of information modelling (Odendaal & Claasen, 2002).

2.10 Design of Experiment (DOE)

Methods of experimental design are chosen in order to minimise the number of necessary tests to establish a rational order and the conditions of the studies. They depend on the type and desired accuracy of the results. For a limited number of tests, the methods provide an estimated accuracy of the result which will be obtained. The methods take into account the random nature of the scattering properties of the test objects and the characteristics of the equipment used. They are based on the methods of probability theory and mathematical statistics.

Experimental Design includes a number of stages (Norusis, 2008). The first stage is Screening, where many variables are evaluated for their significant effect, the second stage is Characterisation where only those variables with the significant effect are studied further, and the last stage is Optimisation. This latter stage is used to study those variables with a curve linear relationship. The Taguchi experimental design method is very efficient since many variables are studied with the minimum number of tests; it is therefore used in this study.

2.10.1 DOE steps:

The general steps involved in the DOE steps (Figure 2-3) are as follows:

1. Establishing the purpose of the experiment.
2. Understanding the experimental conditions.
3. The identification and selection of input and output parameters based on the collection and analysis of preliminary (a priori) information. Input parameters (factors) may be deterministic, that is recorded and controlled (dependent on the observer), and random, that is registrable but unmanageable (Nelson, 2003).
4. Identifying the required accuracy of the measurement of results (output parameters), the field of possible changes in the input parameters, and specification types of impacts. Choose the type of specimens or objects under study, given the degree of compliance with the actual product regarding device, shape, size and other characteristics (Natovich, 2003).
5. Planning and conducting experiments, the number and order of the tests, the method of data collection, storage and documentation of data. The test procedures are important if the input parameters (factors) in the study of the same object in a single experiment take

different values. The order of the tests is also important in the process of exploratory research; the sequence of actions in the experimental search is based on the optimal ratio of the parameters of an object or of a process.

6. Statistical analysis of the results of the experiment, and the construction of a mathematical model of the behaviour of the studied characteristics (Näslund, 2008).

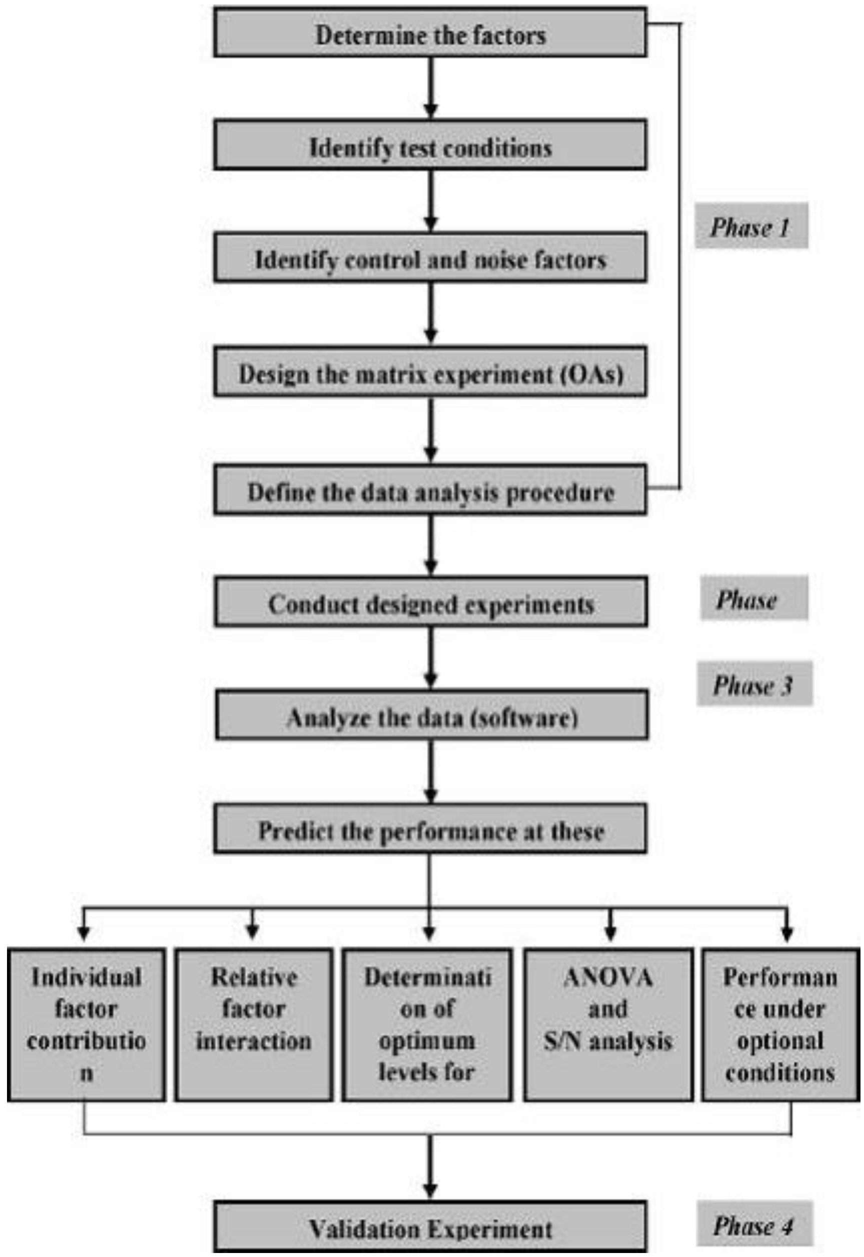


Figure 2-3 Steps involved in the use of DOE

The Taguchi method is a branch of Design of Experiment (DOE) developed by a Japanese Engineer Genichi Taguchi,that assists engineers in designing products or processes so that they are robust against environmental conditions and component variation by minimising variation around a target. Some statisticians have accepted the philosophy inherent in Taguchi methods, specifically studying variation, but have disapproved of Taguchi's application (Rosa, 2009; Selden, 1997). Taguchi’s approach is useful when there are many variables to be investigated and the available resources are limited, especially time (Roy, 2001; Casalino et al., 2005; Ozcelik & Erzurumlu, 2006).

2.10.2 Analysis Of Variance (ANOVA)

Analysis of variance examines the effect of one or more independent variables or one (univariate analysis) or more dependent variables (multivariate analysis). The independent variables take only discrete values (on a nominal or ordinal scale) which are factorial. Independent variables that belong to an interval scale or ratio scale are known as covariates, and the corresponding analysis is known as covariance. The basis of the statistical analysis of variance models is the assumption that in the analysed samples (one or more) parameters are considered normal distribution. The main purpose of the analysis of variance (ANOVA) is to study the significance of the differences between the means using comparison (analysis) dispersions. The division of the total variance in the number of sources allows for comparison of the variance caused by differences between the groups, with a dispersion caused by intra-variability. The null hypothesis (equality of average in several groups of observations selected from the general population) estimate of variance associated with intragroup variability is equivalent to the estimate of intergroup variance (Murugappan, 2003).

For the comparison between the averages of two samples, analysis of variance provides a similar result to a conventional t-test for independent samples (when comparing two independent groups of objects or observations) or to a t-test for dependent samples (when comparing two variables from the same set of objects or observations). The purpose of the analysis of variance is in the taking apart of the total variance in the trait under study of individual components, due to the influence of specific factors, and testing hypotheses about the significance of the impact of these factors (Murray, 2001).

The comparison of the variance components with each other via the Fisher F-test would determine how much of the total variation resultant variable is due to the action of controlled factors. The starting material for the analysis of variance is data from a study of three or more samples: $x_1, \ldots, x_n$ which can be either equal or unequal in size, both connected and disconnected.

The number of identified factors regulated by analysis of variance can be one-factor (the study of the influence of one factor on the results of the experiment), two-factor (the study of the influence of two factors) or multifactorial (allows the evaluation of not only the impact of each factor individually, but also their interaction). Analysis of variance refers to a group of parametric methods and therefore should only be used when it is proved that the distribution is normal.

Analysis of variance is used when the dependent variable is measured on a scale of relation intervals or order, and when influencing variables have a non-numerical nature (scale items).

2.11 5S

5S is one of the methods of Lean production system with the goal of improving the production process, the main objectives of which are to reduce the loss of workplaces and to increase productivity. The 5S system involves organising the workplace and the use of visual cues to achieve the best performance. Being part of a culture of continuous improvement, the 5S system is usually the first Lean method that applies to entities to facilitate the introduction of other methods of Lean production, optimising workflow and processes (Morris & Pinto, 2007).

5S provides the basis for other Lean tools, such as total productive maintenance (TPM), cellular manufacturing, and just-in-time production (Grief, 1995; Hirano, 1995; Peterson & Smith, 1998; Pojasek, 1999; Productivity Press Development Team, 1996; Productivity Press Development Team, 2000, Productivity Press Development Team, 1999; Shimbun, 1995; Tel-A-Train and the Productivity Development Team, 1997).

5S includes five components: Sort (Seiri); Compliance with order (Seiton); Contents clean (SEIS); Standardisation (Seiketsu); and Improvement (Sitsuke). Together, they form a methodology for organising, ordering, developing and maintaining a productive working environment. The 5S system aids the maintenance of organisation and transparency, the most important conditions for continuous and efficient flow of the production process. The successful introduction of the Lean method also improves working conditions and is an incentive for workers to increase productivity and reduce the amount of losses, unplanned downtime and work in progress. The result of the successful implementation of 5S is a significant reduction in materials and space required for the implementation of production processes (Morgan, 2006).

The system includes storage of tools and materials in specially marked colour storage areas, such as baskets and boxes. These conditions provide the basis for the successful implementation of other methods of Lean production such as universal care facilities, flexible manufacturing, and production just in time. The 5S system also prepares the ground and optimises the organisation of processes so that Six Sigma methodologies can be implemented (Montgomery & Woodall, 2008).

2.11.1 Implementation of 5S

The ‘Sort’ phase emphasises removing items from the workplace that are not required for existing production processes. An efficient and effective visual method to classify these superfluous bits and pieces is called "red tagging." A red tag is positioned on all objects not important for operations or not in the suitable location or quantity. Red tag objects are moved to a central stock area for later disposal, recycling, or reassignment depending upon the nature of the material. Organisations mostly observe that sorting empowers them to retrieve valuable floor space and remove such items that belong to the broken category, such as scrap and excess raw material (Survey Money, 2005).

The ‘Set in Order’ phase focuses on building efficient and effective storage and labelling systems to position items so that they are easy to use, easy to search, and easy to put away. Set in Order can only be applied once the Sort process has cleaned the work area of unnecessary items. Approaches for effective Set in Order comprise painting floorboards, sticking on labels and placards to identify accurate storage locations and methods, drawing work areas and locations, and installing modular shelving and cabinet systems.

Once the obstacles blocking the work areas have been removed and the remaining objects have been structured, the next step is to comprehensively clean the work area; this is called the Shine phase. Daily follow-up cleaning is mandatory to sustain the improvement process. Working in a clean environment empowers workers to notice breakdowns in equipment such as fluid leaks, irregular vibrations, damages, and misalignments. A lack of maintenance culture could lead to equipment failure and loss of production. Organisations frequently form Shine objectives, projects, methods, and tools before beginning the Shine pillar.

After implementation of the first three 5S's, standardisation of all the activities in the process work area should be implemented. The standardising activity requires three steps which are: sustaining the first three pillars, and constructing a steady method with which procedures and tasks are completed. The three phases in this process convey 5S (Sort, Set in Order, Shine) and are required to perform job responsibilities, incorporating 5S duties into systematic work duties, and checking on the maintenance of 5S. Some of the tools used in the standardisation of the 5S procedures are: visual cues jobs, cycle charts (for example signs, placards, display scoreboards), scheduling of five-minute periods called “5S periods”, and performing check lists of daily activities in the job area. The second portion of Standardise is prevention by collecting unnecessary items and products from broken pieces of equipment, and protecting equipment and materials from dust.

The ‘Sustain’ phase refers to maintaining the practice of appropriately observing correct 5S procedures. The ‘Sustain’ is the most tasking S to implement as it involves setting goals and objectives and influencing the behavioural culture that exists in the work place. The trend of the entire workspace is often to go back to the status quo and the luxury zone of “the old fashioned way” of doing activities.

The Sustain ‘S’ philosophy outlines a novel status quo and standard for the work place of any organisation. An organisation without the Sustain part of the housekeeping strategy is unsustainable. Tools used for the implementation of sustaining 5S include pocket manuals, team and management check-ins, performance reviews, signs, newsletters and posters, and department tours. Organisations continually strengthen 5S communications with different methods until it becomes “the way things are done” (Montes, 2006).

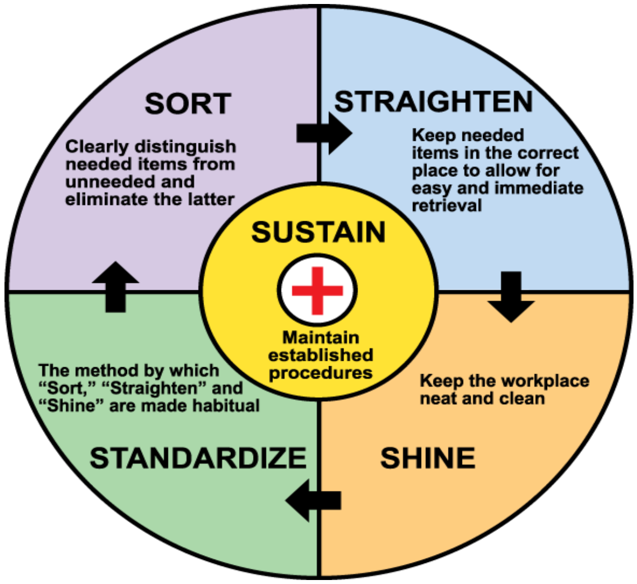


Figure 2-4 The 5S Pillars

2.12 Value stream mapping (VSM)

Value stream mapping is a tool used in the visual demonstration of a process. Value stream mapping is the backbone of the implementation of quality management methods such as "Lean manufacturing (LM)". LM is used to reduce different several types of waste in any organisational setup by restructuring the material and the flow of information. LM can also be used to identify the root cause of the waste. Waste could be defined as any action that ingests resources without creating any value for the customer.

A value stream map classifies all the activities that yield a product by using the manufacturing process with the help of certain raw materials in order to receive the final product. The main idea of VSM is to sketch, on one page, a "map" of the movement of material with the help of production and information flow from the customer and supplier within each production process.

The identification of the value stream requires actions to be taken in order to optimise the manufacturing process by detecting wastes. Low technology is used in value stream mapping by using a pencil and paper method that improves information flow, planning for the business, and complete management of the processes. VSM is not only applied on the shop floor but can also be implemented in each section of the organisation. The steps to generating a value stream map are presented below:

1- Step 1:

The fundamental step is sketching a comprehensive picture of each section of your operation to yield a "current state map", which depicts the current scenario of your business. The whole manufacturing process is mapped out with respect to cycle times, down times, material moved, in-process inventories and flow of information.

2- Step 2:

The second step identifies techniques to mend your process flow that will remove waste from the process and efficiently & effectively utilise time, talent, and equipment. The outcome is an improved understanding of the complete process which describes the future state map.

3- Step 3:

The final step is the implementation of process improvement. This in effect would decrease the work in the process inventory and also reduce lead times, result in fewer defects, and lead to quick reactions to changes in demand. The individuals responsible for constructing a future state map are permitted to make changes through all of the departments and in all areas (Welch, 2005).

2.13 Poka-Yoke

The Poka-Yoke idea was first introduced by the Japanese industrial engineer Shigeo Shingo in the mid-1960s. At that time, Shingo was working for Toyota, where he established complete production systems dedicated to accomplishing zero defects in production.

Poka-Yoke is a Japanese tool used for mistake-proofing to prevent defects from occuring within the production processes. Poka-Yoke is a preventive approach that emphasises recognising and removing the main causes of deviation in production processes, which inevitably lead to product non-conformance or defects. (Lean Six Sigma Operational Delegate Workbook, 2008; Dudek-Burlikowska & Szewieczek, 2009).

Poka-Yoke is an approach and policy for the prevention of defects from the source by adopting cost-effective solutions. Poka-Yoke could be used in any organisation and is vital to continuous improvement programmes. A higher level of performance of the quality management system of any sector can be achieved by adopting the continual improvement Poka-Yoke strategy (Anderson, 2002).

The basic thought behind Poka-Yoke is that it does not allow the production of even a very small number of defective products (Anderson 2002; Dudek-Burlikowska & Szewieczek 2009). To become and remain competitive in global business markets, each individual business must practice and receive benefits of new business philosophies, and this can only be achieved while operating in a zero defects environment. Poka-Yoke is adopted by the majority of Japanese companies in today's business world; its adoption is due to its continual improvement and simplicity whilst implementing. Kazien is another familiar example of Poka-Yoke, or a superior continual improvement programme due to its preventive nature.

The Poka-Yoke solution mechanism either prevents or detains mistakes at first sight. The capability to discover mistakes at first sight is most vital because, as Shingo states, "The causes of defects lie in worker errors, and defects are the results of neglecting errors. Mistakes will not turn into defects if worker errors are discovered and eliminated beforehand" (Shingo 1986, Grout & Downs, n.d.). Shingo also stated that "Defects arise because errors are made; the two have a cause-and-effect relationship. Yet errors will not turn into defects if feedback and action take place at the error stage" (Shingo 1986, Grout & Downs, n.d.).

During the manufacturing of products, there are many simple and repetitive steps which are performed by operators. These tedious work actions result in mental fatigue and negligence that finally cause mistakes, resulting in defects of the produced parts (Lean Six Sigma Operational Delegate Workbook, 2008). The Poka-Yoke strategy presents simple solutions for these problems in order to escape from these errors. The long-term success of Poka-Yoke confers value in terms of saved time and reduction in operator stress.

2.13.1 Poka-Yoke Benefits

Poka-Yoke prohibits production and performance breakdown, eliminating waste materials and lost productivity by adjusting faults or minimising defective products. Initially, Poka-Yoke was used as part of Lean manufacturing which concentrated on productivity and its speed while minimising defects and rework. Consumers believe in defect-free products. The Poka-Yoke strategy predicts defect or failure in advance, to provide 100% prevention (Dudek-Burlikowska & Szewieczek 2009).

2.13.2 Types of Poka-Yoke

Poka-Yoke is a practice to reduce or eliminate human error. A defect or failure occurs in one of two situations: the defect has previously occurred and requires defect detection, or it is about to occur and requires defect prediction. The method starts by investigating the process for possible errors, recognising parts on the basis of certain factors like dimension, shape, and weight, detecting process deviation from the nominal value. Depending on the fundamental functionality, Poka-Yoke has three types:

1. Shutdown (Prevention) Poka-Yoke: This method stops processes at the point that they cross permissible tolerances.
2. Control Poka-Yoke: This could be implemented in any business setup by considering factors such as equipment, packaging, or products that avoid inappropriate positioning or terms of use.
3. Warning (Alert) Poka-Yoke: This method for Poka-Yoke does not technically deliver 100% prevention of defects or failures, but rather warns the operator of a situation that needs correction (Lean Six Sigma Operational Delegate Workbook, 2008).

In summary, this chapter reviewed the current literature pertaining to Lean, Six Sigma, Lean Six Sigma and the topic at hand, LSS & OHSMS. Lean was derived from the Toyota Production System, and has been interpreted by researchers. Six Sigma was invented by Motorola, and has evolved since its conception. The distinctness (as compared to Lean and Six Sigma individually) and diversity (as one model is compared to another) of Lean Six

Sigma was explored. The role of the Lean Six Sigma theory was summarised. The evolution of Lean Six Sigma, leading to the consensus that such a hybrid is desired, was described.

Eliminating potential errors in the SBC's process is the primary objective of this research. Regulations were issued by the International Labour Organisation in 2001 for the purpose of protecting workers from occupational hazards and eliminating or controlling work-related hazards, ill health, diseases, incidents and deaths. SBC's OSHMS is based on ILO's regulations in the field of occupational health and safety (ILO, 2001; Walker, 2009). By following ILO guidelines, a complete OSH management system can be designed (Appendix C). A simple Questionnaire was distributed in November 2011 to 50 engineers in SBC to introduce Lean Six Sigma (LSS) and ascertain their opinions about the implementation of LSS to improve OSHMS (Appendix A). Their answers support the concept of integrating LSS and OSHMS in SBC to minimise risks and eliminate waste.

Finally, research needs were identified in the literature. The next chapter describes the methodology that was deployed in order to assess existing Lean Six Sigma models, and develops an optimal Lean Six Sigma model based upon the data collected and analysed.

CHAPTER 3: METHODOLOGY

3.1 Overview

The research objective is to identify and minimise hazards in the media industry through systematic identification and exploration of major hazards and their contributing process variables. The study is structured for media industry hazards applying the Six Sigma DMAIC (Define, Measure, Analyse, Improve, and Control) model and associated methods. Statistical modelling is used to prioritise, explore, and lay the foundation for improving and controlling the identified hazards.

This chapter provides an overview of the methods used. The following two chapters (Chapters 4 and 5) provide the results of the work and this is briefly summarised in the table below:

Table 3-1 DMAIC framework

	DMAIC Phase	Objective	Methods
Chapter 4	Define	Define problem	• Project Charter
	Measure	Understand Current Process State	• Data Collection • Pareto Charting (All Hazards) • Value Stream Mapping
	Analyse	Analyse Root Cause of the Problem	• Cause and Effect Diagram • Process Failure Mode and Effects Analysis • Pareto Charting (Hazard Root Causes) • Bayesian Belief Network Analysis
Chapter 5	Improve	Improve Process Performance	• Taguchi Methodology • 5S Methodology • Value Stream Mapping • Poka-Yoke
	Control	Sustain Process Improvement	• Post Intervention Failure Mode and Effects Analysis • Post Intervention Bayesian Belief Network Analysis • Statistical Process Control: NP-Charts

The methods listed in Table 3-1 were selected based on the Lean Six Sigma DMAIC tools that helped to obtain the goal of reducing errors and safety risks. For example, 5S implementation will improve safety, Value Stream Mapping will improve efficiency, Poka-Yoke will minimise errors, and the Taguchi method will help to reduce process errors.

3.2 DMAIC Define Phase

The DMAIC Define Phase seeks to understand the voice of the customer, to identify customer needs, and to identify the Critical to Quality (CTQ) characteristics to be addressed, ensuring that CTQs are physical, measurable effects directly linked to the customers' expressed requirements. To achieve this, the project is described in a project charter that includes the following elements:

a) General project information such as title and process definition.

b) Identification of project members who provide project support.

c) A business case for the initiation of the project.

d) A problem statement that describes the issue to be addressed.

e) A description of the project objectives as expressed by the customer.

3.3 DMAIC Measure Phase

The DMAIC Measure Phase seeks to achieve a quantified understanding of the project elements. In this phase, the existing environment is objectively characterised and the CTQs are further defined. This phase includes the following analytical techniques:

3.3.1 Data Collection

A survey of the existing physical environment and historical corporate data related to prior hazard events was conducted. Data collection was conducted as an iterative process, where initial information was used to clarify and seek additional information, until the current situation was fully characterised using primary sources. Accident data was collected from historical data records at Saudi Broadcasting Corporation in December 2011.

3.3.2 Pareto Analysis

Pareto analysis is used to visually highlight the most significant hazards and, subsequently, the most significant root causes for each identified hazard. The Pareto chart provides a ranked comparison of the identified media industry hazards (and, later, hazard root causes) to identify those hazards (and root causes) presenting the most significant negative effects within the customer's environment. Pareto analysis is used to focus project efforts on the "vital few" hazards or root causes to maximise the benefits realised by the project's efforts. For the purposes of this project, the "vital few" contributors were identified as those that accounted for 80% of the cumulative effect of the examined elements. The data collected identified a limited number of elements exerting a variety of individual levels of effects and it was therefore found to be appropriate for Pareto analysis. If the data collection had resulted in a large number of elements, each exerting a roughly similar effect, then Pareto analysis would not have been useful.

3.3.3 Value Stream Mapping

Value stream mapping is used to visually represent the media industry processes associated with hazards targeted for further study. Value Stream Maps (VSMs) are used to aid in identifying resource wastes and, subsequently, the source of those wastes. For the purposes of this effort, waste is defined as activity that consumes resources (raw materials, time, information, etc.) but provides no associated value for the customer.

VSMs enable optimisation of media industry processes by providing a visual communications approach to ensure process clarity and to support future activities, such as 5S, business planning, and overall management. For this effort, VSMs were used to:

- Produce a detailed picture of each relevant part of the operation to produce a "current state map" of the situation as it exists today. The entire process is mapped out, including cycle times, down times, in-process inventory, material moves, and information flow paths.

- Identify ways to improve process flow to eliminate waste and utilise time, talent, and equipment more efficiently. This invariably results in a better understanding of the entire process. These improvements define the future state map.
- Guide the implementation of process improvements, which leads to a reduction in work-in-process and production lead times, fewer hazards, and faster responses to changes in demand.

3.4 DMAIC Analyse Phase

The DMAIC Analyse phase uses quality control tools to better understand the potential causes of hazard events through analysis of the past and current process performance data. This phase will develop a better understanding of the difference between the performance of the current process and the desired process performance, specify goals that the project is seeking to accomplish, define how success is to be measured, and identify the root causes of the problem. Pareto Charting has already been described above; other methods used include:

3.4.1 Cause-and-Effect Diagram

The cause-and-effect diagram is used to represent the relationship between hazard effects, the problem being studied, and their possible causes. It allows systematic exploration of all possible causes through brainstorming techniques. It was developed by Kauru Ishikawa to help a group focus on specific issues for improvement in a linear process (Johnson & Johnson, 2003). The cause-and-effect diagram was used to focus on the root causes of the hazards earlier identified as "the vital few" for focus. Systematic brainstorming of potential contributing factors to each hazard enabled a complete understanding of the current state of operations. A complete cause-and-effect diagram aids with the discovery of root causes when a single contributing factor, such as lack of experience, appears frequently as a secondary contributing factor to primary contributing factors. Finally, the cause-and-effect diagram provides a starting point for a Lean Six Sigma team to decide what data to collect, and which actions to take based on the possible causes associated with the identified problem. The process followed is listed below:

- Brainstorming session was conducted.

- Selected categories include materials, machines, manpower, methods, measurement and environment.
- Potential causes were identified.
- Sub-causes were identified as long as the problem areas could be further subdivided.
- The maximum practical depth was four levels.

3.4.2 Failure Mode and Effects Analysis

Failure Mode and Effects Analysis (FMEA) systematically quantifies the potential effect of a failure, also called a "failure mode," in each identified step of the studied process. Using FMEA, each failure mode is numerically scored as a Risk Priority Number (RPN). The cumulative RPNs for the evaluated process indicate either the process's current state (as it exists now) or a potential, hypothetical, state under different failure prevention scenarios.

RPNs are calculated by numerically scoring each failure mode on three aspects: (a) the likelihood that the failure will occur; (b) the likelihood that the failure will be detected; and (c) the amount of harm or damage that the failure mode may cause to a person or equipment. The product of these three scores (Severity x Occurrence x Detection) is the Risk Priority Number (RPN) for that failure mode. The sum of the RPNs for all failure modes associated to the process is the overall RPN for the process.

High RPNs are an indicator of a need for corrective action. It is recommended that action be taken for any RPN over 50. As the Saudi Broadcasting Corporation works to improve their processes, they can use hypothetical RPNs of proposed scenarios as an option in evaluating contemplated changes. It should be noted that RPNs are specific to a single process. Overall process RPNs are not intended to be compared to other processes or other organisations.

The three failure mode aspects are scored using a ranking table that is created and agreed to in advance of scoring activities. A table is created for each aspect: severity evaluation criteria, occurrence evaluation criteria, and detection evaluation criteria.

3.4.3 Bayesian Belief Network

The Microsoft Bayesian Network Tool Kit (MSBNx) was used to model Bayesian Belief Networks (BBNs) of the identified "vital few" hazard effects. Unlike FMEAs, the BBNs enable probabilistic evaluation of each considered hazard in light of the probability of identified causes. The method, applies actual observed data for the existing environment to verify and further quantify findings from prior methodologies. Sensitivity analysis of the probability of the various identified causes enables accurate prediction of the impact of the proposed corrective actions on the future probability of the examined hazard effect. Finally, after implementation of the proposed interventions, BBNs are used as part of the monitoring process in the DMAIC Control Phase to maintain an accurate understanding of the benefits realised by the implemented interventions and the residual probabilities of the monitored hazard effects.

A simple questionnaire (Appendix D), which included direct questions about the causes' probabilities, was distributed to 50 engineers in the Saudi Broadcasting Corporation who have practical experiences in the process; the data were then collected and analysed (Appendix D). Software such as Microsoft Believe Networks (MSBN) and Arena served as the analytical software to collate and model the data gathered from the questionnaires.

3.4.3.1 BBN Assessment for Hazards

A BBN of electrical hazard and associated causes is provided in Figure 3-1. The BBN technique will be applied in this study in order to find out the influence of causes on electrical hazards. This technique as a result will estimate the hazard probability. The BBN enables sensitivity analysis, through manipulation of the probabilities of individual causes, and allows analysis of the comprehensive impact of each intervention considered on the overall electrical hazard probability.

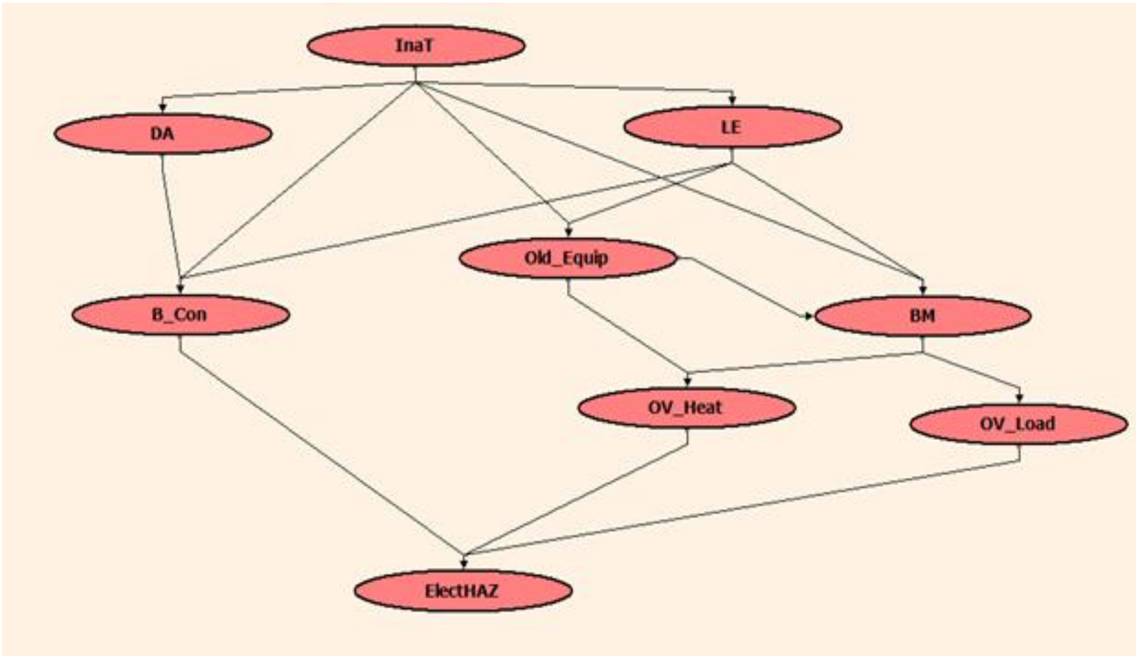


Figure 3-1 A BBN network for electrical hazard

Table 3-2 Present sample data tabulated from questionnaires for electrical hazard

Employee ID	InaT	LE	DA	B_Con
1	Y	Y	Y	Y
2	Y	Y	Y	Y
3	Y	Y	Y	N
4	Y	Y	N	N
5	N	Y	Y	Y
[...]				
47	N	Y	Y	Y
48	N	Y	N	N
49	N	N	Y	Y
50	N	N	N	N

Based on Table 3.2, there are three variables, namely: "Inadequate Training" (InaT), "Lack of Experience" (LE), and "Disorganised Area" (DA) that affect the variable "Bad connector" (B_Con). All of these variables have two conditional probability states, "Yes" and "No". The complete conditional probability table for the Electrical caused Hazard is shown in Appendix D.

3.4.3.2 Sensitivity analysis

Sensitivity analysis provides a method to determine how different probability values of an independent variable will impact a particular dependent variable under a given set of assumptions. Therefore sensitivity analysis was employed to project and compare the potential influence of improvement among selected root causes.

Electrical Hazard Sensitivity Analysis: Mitigation of lack of experience (LE) (to a probability of 0.00).

In this sensitivity analysis, lack of experience is assigned the probability of 0.00 (implying that lack of experience is never a causal factor), and the probability of Electrical Hazard is observed. The updated conditional probability values in the BBN under these conditions will be shown in the next chapter.

3.4.3.3 Probability Calculation:

The application of known probabilities could be used to calculate the probability of fire hazards, by summing the various combinations in which the occurrence of fire hazard is true, and breaking those probabilities down into known probabilities:

Table 3-3 Data of fire hazard probability

B_CON	**Flam_Mat**	OV_Heat	Fire caused hazards		Total
			Yes	**No**	
Yes	**Yes**	**Yes**	**0.25(4/16)**	**0.75(12/16)**	**16**
		No	**0.2(1/5)**	**0.8 (4/5)**	**5**
	No	**Yes**	**0.2 (1/5)**	**0.8 (4/5)**	**5**
		No	**0 (0/9)**	**1(9/9)**	**9**
No	**Yes**	**Yes**	**0 (0/0)**	**1(1/1)**	**1**
		No	**0.2 (1/5)**	**0.8(4/5)**	**5**
	No	**Yes**	**0 (0/1)**	**1 (1/1)**	**1**
		No	**0.375(3/8)**	**0.625(5/8)**	**8**
Total			**10**	**40**	**50**

P(FIRE_HAZ) = p(FIRE_HAZ |B_CON,FLAM_MAT,OV_HEAT) * p(B_CON) * p(FLAM_MAT) * p(OV_HEAT) +p(FIRE_HAZ | B_CON,FLAM_MAT,~OV_HEAT) * p(B_CON) * p(FLAM_MAT) * p(~OV_HEAT) + p(FIRE_HAZ| B_CON,~FLAM_MAT,OV_HEAT) * p(B_CON) * p(~FLAM_MAT) * p(OV_HEAT) + p(FIRE_HAZ | B_CON,~FLAM_MAT,~OV_HEAT) * p(B_CON) * p(~FLAM_MAT) * p(~OV_HEAT) +p(FIRE_HAZ | ~ B_CON,FLAM_MAT,OV_HEAT) * p(~B_CON) * p(FLAM_MAT) * p(OV_HEAT) +p(FIRE_HAZ |~ B_CON,FLAM_MAT,~OV_HEAT) * p(~B_CON) * p(FLAM_MAT) * p(~OV_HEAT) + p(FIRE_HAZ |~ B_CON,~FLAM_MAT,OV_HEAT) * p(~B_CON) * p(~FLAM_MAT) * p(OV_HEAT) +p(FIRE_HAZ |~ B_CON,~FLAM_MAT,~OV_HEAT) * p(~B_CON) * p(~FLAM_MAT) * p(~OV_HEAT)

P(FIRE_HAZ) = 0.25 * 0.7 * 0.53 * 0.54 +0.2 * 0.7 * 0.53 * 0.46 + 0.2 * 0.7 * 0.47 * 0.54 + 0 * 0.7 * 0.47 * 0.46 + 0 * 0.3 * 0.53 * 0.54 + 0.2 * 0.3 * 0.53 * 0.46 + 0 * 0.3 * 0.47 * 0.54 + 0.375 * 0.3 * 0.47 * 0.46

P(FIRE_HAZ) = 0.05+0.034+0.0355+ 0+0+0.0146+0+0.024
= 0.158

So as a result of the conditional probabilities, fire hazard has a 0.158 chance of being true in the absence of any other evidence.

3.5 DMAIC Improve Phase

The DMAIC Improve Phase seeks to identify, assess and implement effective solutions to the identified hazard effects. In this phase, the determining of the relationship between process input variables and process outputs, or CTQs, was implemented by applying the design of experiment method. Design of experiment utilises a series of structured tests where deliberate changes are introduced to the process input variables to evaluate their effect on the process output variables or responses. This approach enables the development of accurate mathematical equations to describe the studied processes that are subsequently used to predict, improve, and optimise the process performance.

3.5.1 DOE (Taguchi Method)

The Taguchi Method, also called the Robust Design method in some countries, provides a scientifically disciplined approach for evaluating and implementing improvements in products, processes, materials, equipment, and facilities. The Taguchi Method was used to improve the desired design of experiment characteristics while simultaneously reducing the number of defects, by focusing on the key variables controlling the process and optimising the procedures or design to yield the best results.

3.5.1.1 Applying Taguchi method to reduce the fire hazard

The Improve phase seeks to identify sources of variations, minimise noise factors, and optimise the process to prevent fire hazards. In this section the experiment applied the Taguchi L16 experiment to identify the sources of fire risks in order to minimise them. The detail of the experiment is discussed in the following section.

3.5.1.2 Equipment used in the experiment

- Extinguishers: class A and B extinguishers will be used (Foam Extinguisher).
- The burned material: a crib of wooden sticks will be used as a burned material.
- Tray containing heptane to light the fire.
- Personal protective equipment.

3.5.1.3 Experiment Assumptions

The experiment tests were subjected to the same conditions, which means that the place, the burning material and the extinguishing method are the same in all the tests.

3.5.1.4 Experiment Conditions

The test room for the experiment was enclosed with the exception of a small opening at the base of the door (provided for ventilation). The wood class and dimensions used in the test are shown in Table 3.4.

Table 3-4 Wood crib dimensions

CLASS	DIMENSIONS (m)
White Wood	0.5*0.5*0.5

The wood cribs are fixed at 50 cm above floor level. A properly sized tray is placed beneath the crib at 30 cm from the wood cribs (see Figures 3-2 and 3-3. The appropriate quantity of heptane starter charge is poured into the tray. The heptane charge is ignited and allowed to ignite the wood crib above. The wood crib is allowed to burn for a period of 30 seconds before extinguishing, see Figure 3-4.

For each run, the following steps should be followed:

- Put the wood crib at the centre of the experiment room, and place a tray full of heptane under it to light the fire.
- Ignite the heptane.
- Start the extinguishing process after 30 seconds from removing the tray.
- Record the time spent in the extinguishing process, and the percentage of damage to the wood for each trial.

Figure 3-2 Wood crib set up

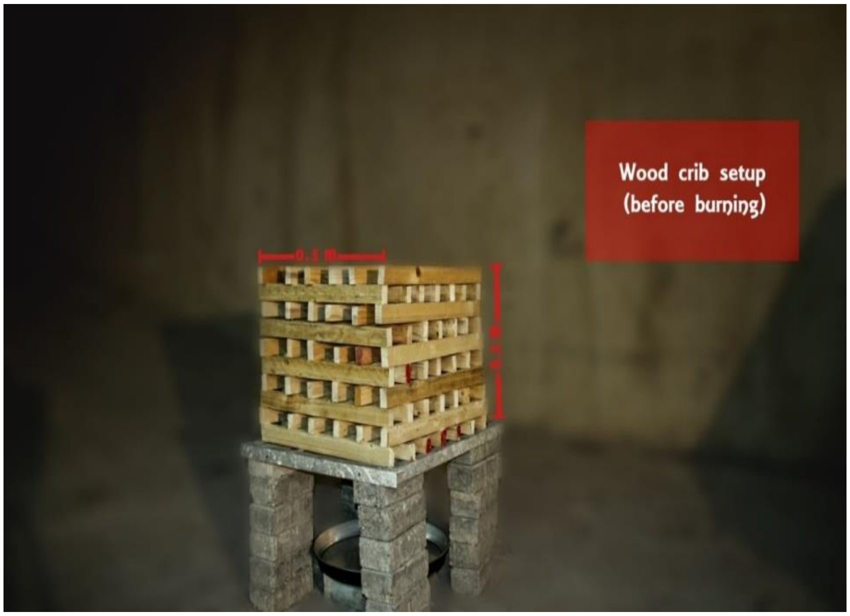


Figure 3-3 Wood crib before burning

Figure 3-4 Fire before extinguishing

3.5.1.5 Determining factors for the study

The teamwork included 10 expert engineers (Electrical, Mechanical, Décor and safety engineers) in SBC, who brainstormed and decided that the human factors/parameters would be included in the study, as they influence the performance of an employee in using the extinguisher. These factors are as follows:

a) **Training**: it is expected that there is difference between the performance of trained employees and untrained employees.
b) **Experience**: employees with more experience may perform better in the extinguishing process. It is worth mentioning that the expert employee is already a trained employee.
c) The **response** to the alarm: faster response to the alarm may lead to the best scenarios.
d) **Age**: employee age directly affects the physical and mental behaviour of the employee, therefore it affects his performance.
e) **Qualification**: higher qualification is predicted to lead to better performance.

The response variables to be measured and improved are:

a) **Extinguishing time**: a measure of the employee's performance and measured in seconds.
b) **Percentage of damage**: the percentage of damage caused by the fire. It is believed that there is a correlation between the extinguishing time and the percentage damage; the longer extinguishing time, the higher the percentage of damage.

3.5.1.5.1 Determining the levels of the factors

The Process parameters and their levels used in the experiment are summarised in Table 3.5.

Table 3-5 Factors and their levels

Factors	Code	Level 0	Level 1
Training	T	Untrained	Trained
Experience	X	without experience	with experience
Response to the alarm	R	>30 sec.(Slow response)	≤ 30 sec. (Fast response)
Age	G	> 40 Years old	≤ 40 Years old
Qualification	Q	<Bachelor	≥ Bachelor

3.5.1.5.2 Orthogonal Array Matrix Experiment

The Taguchi Orthogonal Array L_{16} design was used (Table 3.6) which included 5 factors and 16 runs. Columns of L16 (2**15) array are chosen that are 1, 2, 4, 8 and 15. The L16 is a resolution III design which means the main effect is confounding with two factor interaction. The alias structure for L16 (Figure 3-5) is summarised below:

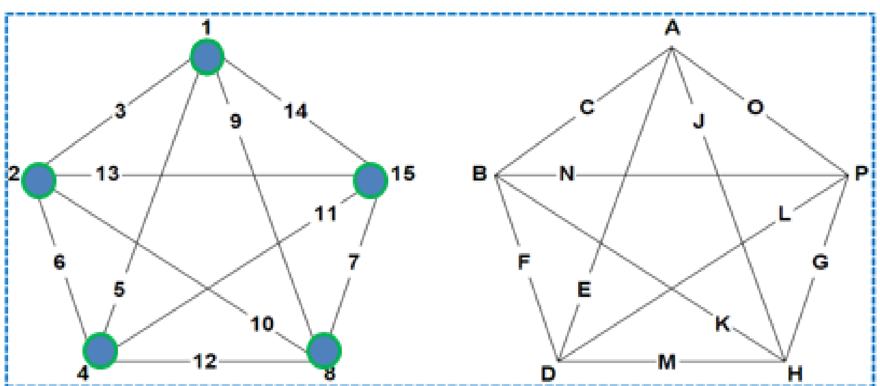


Figure 3-5 The alias structure for L16

In Figure 3-5 on the left are 15 column numbers available for effect estimation, and on the right are the corresponding factor letters. Starting at the top and going counter clockwise, you can see that factor C is connected to AB, implying confounding of factor C with AB interaction.

Table 3-6 L16 Orthogonal array design matrix

16 runs evaluating 5 factor effects: 16 employees, Male

Run #	**Factors**				
	T	X	R	G	Q
	1	2	4	8	15
1	0	0	0	0	0
2	0	0	0	1	1
3	0	0	1	0	1
4	0	0	1	1	0
5	0	1	0	0	1
6	0	1	0	1	0
7	0	1	1	0	0
8	0	1	1	1	1
9	1	0	0	0	1
10	1	0	0	1	0
11	1	0	1	0	0
12	1	0	1	1	1
13	1	1	0	0	0
14	1	1	0	1	1
15	1	1	1	0	1
16	1	1	1	1	0

The Taguchi method recommended that the standard eight-step optimisation procedure was used to evaluate and develop new understanding of key factors affecting fire hazard events.

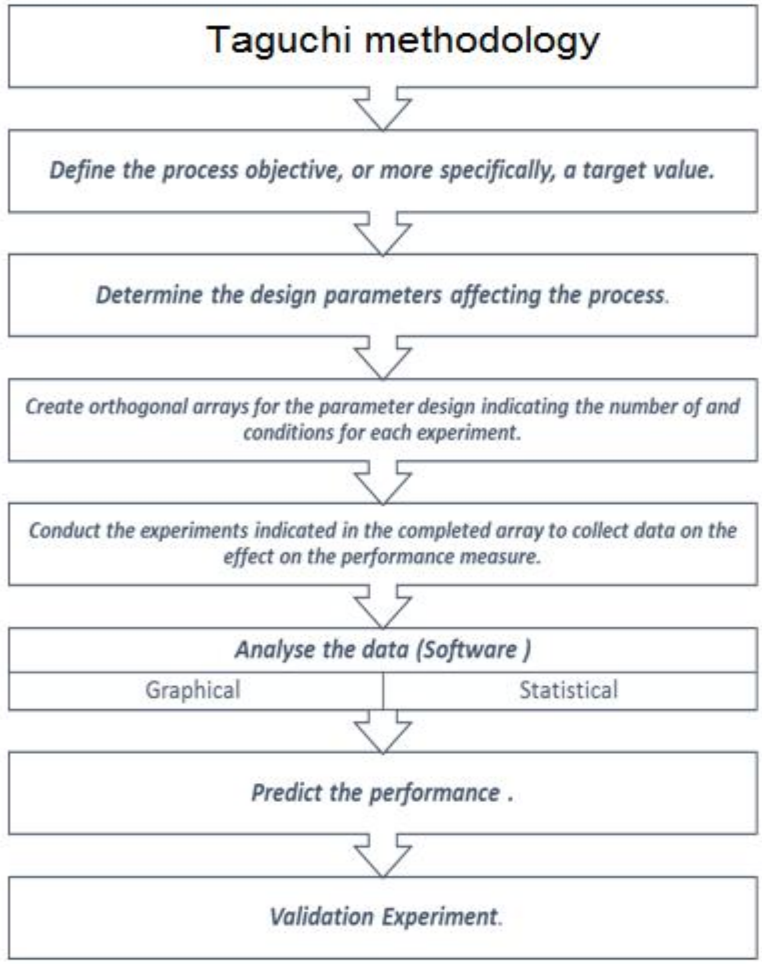


Figure 3-6 Set followed in Taguchi method

3.5.2 5S

The 5S methodology was used to reduce waste, establish an orderly workplace, and establish a sustainably productive work environment in the Saudi Broadcasting Corporation environment. The 5S methodology provides a structured means to simply, clean up, and organise working environments. Originally developed in Japan, it is based on five pillars, Sort (Seiri), Set in Order (Seiton), Shine (Seiso), Standardise (Seiketsu), and Sustain (Shitsuke).

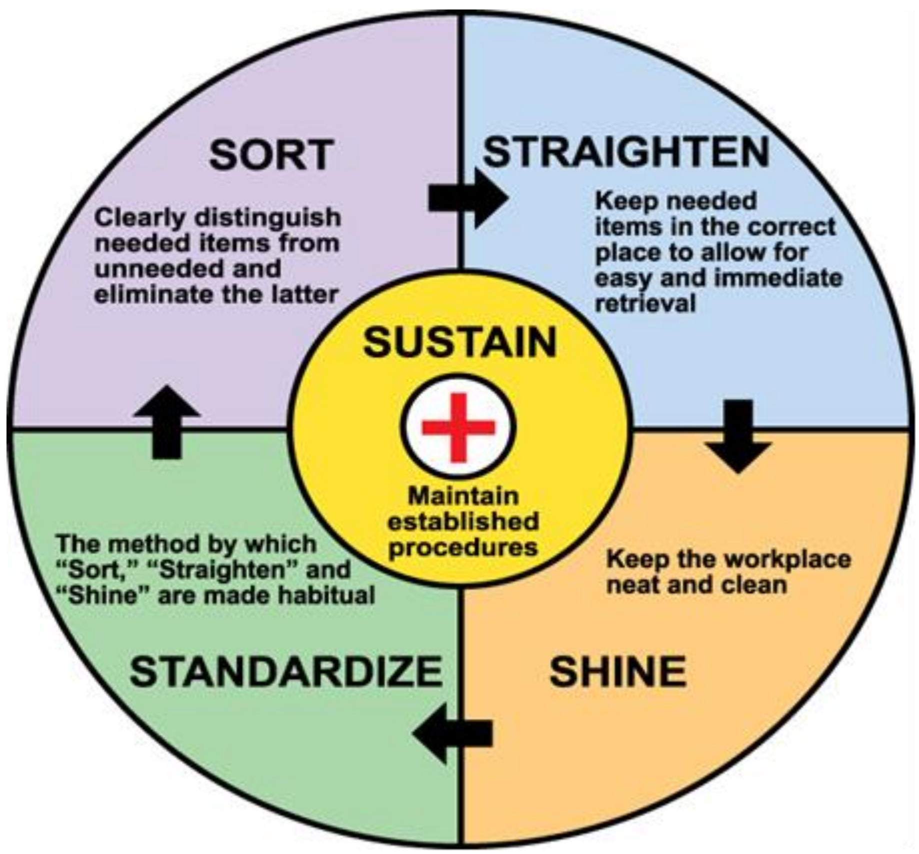


Figure 3-7 The 5S Pillars

A 5S Audit Form (Appendix D) was developed to provide the basis for employee training in the objectives and benefits of the 5S philosophy, to assess the current state of the environment, and then provide periodic audits to ensure sustained progress towards the 5S goals.

3.5.2.1 The 5S Method and Implementation Approach

The 5S is a cyclical methodology refered to as Sort, Set in order, Shine, Standardise, and Sustain the cycle. It helped to create a better work environment in the Saudi Broadcasting Corporation. To implement 5S in the media industry, the following 5S points and steps were followed (Appendix E):

- Use 'Seiri - organisation' to eliminate unnecessary items.
- Use 'Seiton - neatness' to establish a permanent place for everything essential.
- Use 'Seiso - Cleaning' to find ways to keep things clean and to eliminate contamination.
- Use 'Seiketsu - Standardisation' for easy inspection.
- Use 'Shitsuke - Discipline' to ensure proper methods of handling production activities.

The 5S implementation steps:	
1. Sort Out	
a- Study	b- Red tag technique
Decide what you need during work	Place the suspected unwanted items in red tag area for one week
Remove unnecessary items at work place	Allow the employees to re-evaluate the required items
Classify all tools, materials and store	At the end of the week those required items should be returned
Remove items which are broken or unusable	
2. Set in Order	
a- Study	**b- Suggestions**

Organise the layout of tools and equipment used by employee in media industry	Rack should be placed at somewhere in rehearsal room where every performer should keep his/her luggage
Designated locations	Luggage which is frequently used must be placed in the first column of the rack
Use tape and labels	Insulation tapes and power grip tapes should be placed in the last column of rack
Make sure that everything is available as it is needed and at the point of use for artist/performer	Make-up required for performer adjustment should be available near each rack in each room
	Plastics unused items should be kept in the scrap place available
	Time clock should be monitored and each performer /employees (Newscaster) should prepare early to be the on air
3. Shining	
a- Study	**b- Suggestions**
Focus on removing the need to clean	Attach waste bins under each section's table in which to place used tape and the thread that came with the bags
Identify and eliminate the causes of dirt	Paint the plant and air conditioning pipes with attractive colours
Sweep, polish and paint	Permanent numbering should be applied onto the waste bins to eliminate the need of pasting stickers every time and then removing those stickers
	Fans and walls should be cleaned regularly to avoid dirty atmosphere
	Cleaning the work place should be the responsibility of each individual
4. Standardise	
a- Study	**b- Suggestions**

Generate the maintenance system for the first three S	Procedures which have been developed by each department (production, promotion, sale, IT) should be implemented and improved continuously according to the needs
Develop procedures, schedules and practices	Procedures should be written in easy language and be visible to the whole work force/Employees
	Checklists should be prepared to audit regularly the implementation of 5 S (Evaluation)
5. Sustain	
a- Study	**b- Suggestions**
Continuous driving force behind 5 S	All the employees should be trained to maintain 5S
Make it a way of life	All the employees of the media industry and helpers should be motivated continually to maintain 5S
Involve the whole work force	Maintenance of all equipment should be planned and the plan should be implemented
	Commitment of each department in charge should be at high level
Saudi Broadcasting Corporation	

3.5.3 Poka-Yoke

Poka-Yoke, a Japanese term that means "mistake proofing," was originally developed as a means of error-proofing manufacturing processes through, often, physical mechanisms that either alert the operator to errors before they happen or physically prevent errors from happening. Key aspects of the existing environment were re-designed incorporating Poka-Yoke concepts that enhanced operations' efficiency while reducing hazard probabilities.

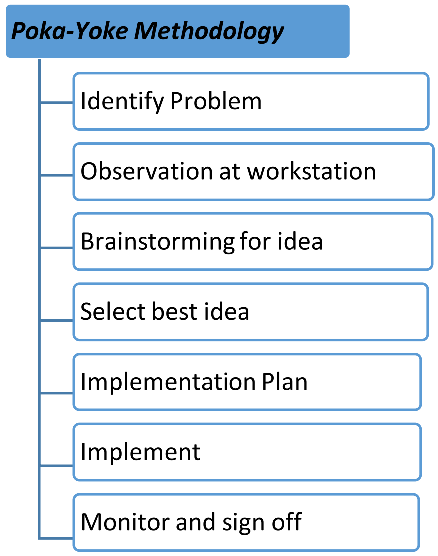


Figure 3-8 Steps of Poka-Yoke implementation. Dudek-Burlikowska et al., 2009.

3.6 DMAIC Control Phase

The objective of the DMAIC Control Phase is to sustain the improvement achieved in the previous phase by assuring stable processes. Further to this aim of DMAIC, controls and quality plans to monitor and maintain the improvements realised were implemented, including checks and balances on process inputs required to maintain improvements and guard against rising probabilities of hazards. FMEA and BBNs have been previously described. In addition, the following method was used.

3.6.1 Statistical Process Control

Statistical Process Control (SPC) provides statistical methods to monitor and analyse variation within a system or process. SPC were implemented to monitor and report project outcomes. C-chart is a type of control chart used to monitor the total number of events occurring in a given unit of time. Observations made on the events are the number of accidents occurring per month. It is used to monitor count data which is assumed to have come from a Poisson distribution with parameter μ; this value is both the mean and the variance. μ is the average number of accidents and is estimated from the data. The number of accidents occurred is plotted versus time. μ is also the centre line on the C chart and it is used to calculate the control limits.

In summary, this chapter outlines the methods used in this study and their purpose and these are summarised below.

The define phase:

Method	Purpose
Project charter	Define the purpose of the project

The measure phase:

Method	Purpose
Data collection	Assesses process
Pareto analysis	Highlights the most significant hazards
Value stream mapping	Improves process cycle time

The analyse phase

Method	Purpose
Cause-and-effect diagram	Identifies the relationship between hazard effects, the problem being studied, and their possible causes
Failure Mode and Effects Analysis (FMEA)	Quantifies the potential effect of a failure, also called a "failure mode," in each identified step of the studied process

Microsoft Bayesian Network	Models Bayesian Belief Networks (BBNs) of the identified "vital few" hazard effects

The Improve phase

Method	Purpose
Taguchi Method	Identifies significant factors that influence hazard risks
5S	Improves safety, reduces waste, and establishes an orderly workplace
Poka-Yoke	Mistake proofs processes

The control phase

Method	Purpose
Statistical Process Control (SPC)	Monitors and analyses process variations

CHAPTER 4 : DEFINE, MEASURE AND ANALYSE

In this chapter, the first three DMAIC phases (define, measure, and analyse) are used to formalise the understanding of health and safety risks as they existed in the Saudi Broadcasting Corporation site that was the subject of this investigation. In the next chapter, the final two DMAIC phases (improve and control) will be used to select, implement, and monitor the progress and results of intervention strategies to address those risks.

4.1 DMAIC Define Phase

4.1.1 Project Charter

The Saudi Broadcasting Corporation manages several radio and television stations and has decided to prioritise worker health and safety. The objective of the Saudi Broadcasting Corporation is to reduce risk through continuous process improvement of its safety processes. At the outset of this effort, deployment and implementation of a continuous improvement technique, such as Lean Sigma, had not yet been undertaken. This research offers a new methodological approach that integrates both established health and safety management systems and Lean Six Sigma techniques to identify and control potential hazards and to minimise accidents.

4.1.2 Problem Definition

Within the Kingdom of Saudi Arabia, the media industry, for example TV and radio broadcasters, is experiencing rapid growth. As a result, at SBC, risk is a topic of increasing concern. The SBC consists of radio, TV, and cable broadcasters. The scope of this study includes motion picture/television production and distribution which include major studios, independent film production companies, and television production, including reality television. Due to the nature of the entertainment industry, the variable and uncontrolled environments of shootings, rehearsals, and events there is always an element of risk. The risks in the entertainment and media industry involve falls from heights, electric short circuits, flash lightning, fire, and many more.

4.1.3 Objective

The objective of this study is to mitigate risk in the entertainment and media industry in each department, at any level or stage of production. Risk mitigation will provide a safe environment and, as a result, increased profits due to enhanced employee satisfaction. The researcher's intention is to examine the risks present in each part of the media industry, to classify and prioritise those risks, and, subsequently, determine the causes for each risk. The author uses root cause analysis to reach a clear understanding of how to minimise or eliminate each risk. Then, after mitigation, the entire environment will be re-evaluated to allow a comparative analysis of the initial state and final state and establish control mechanisms.

4.2 DMAIC Measure Phase

In this phase, business processes and their overall performance are evaluated using two tools, Pareto charting, and Value Steam Mapping of the current environment.

4.2.1 Data Collection

Evaluation of the current Saudi Broadcasting Corporation site layout found: unsafe construction, congested workplaces, and overloaded electric wiring. The overall conclusion reached is that current workplace environment presents hazardous conditions. Accident data, including causal factors, was collected from historical data records at Saudi Broadcasting Corporation in December 2011. The data is presented below in Table 4.1 in descending order of Frequency of Occurrence per Annual.

Table 4-1 Record of accident numbers, Dec. 2011

Type of Hazard	**Frequency of Occurrence per Annual**
Fall Hazards	36
Electrical Hazards	25
Fire caused Hazards	15
Outdoor Events Hazards	5

Type of Hazard	Frequency of Occurrence per Annual
Fatigue Hazards	4
Noise Hazards	3
Laser Hazards	2
Staging, Performers on Stage Hazards	2
Smoke Strobe lighting Hazards	1
Ultraviolet light Hazards	1
Pyrotechnics Hazards	1
Naked Flame Hazards	1
Total	96

4.2.2 Pareto Chart

The data collected was used to construct a Pareto chart representing all reported types of hazard along the horizontal axis in descending order of frequency from left to right. The left vertical axis represents the frequency of occurrence. The right vertical axis represents the cumulative percentage of the total number of occurrences.

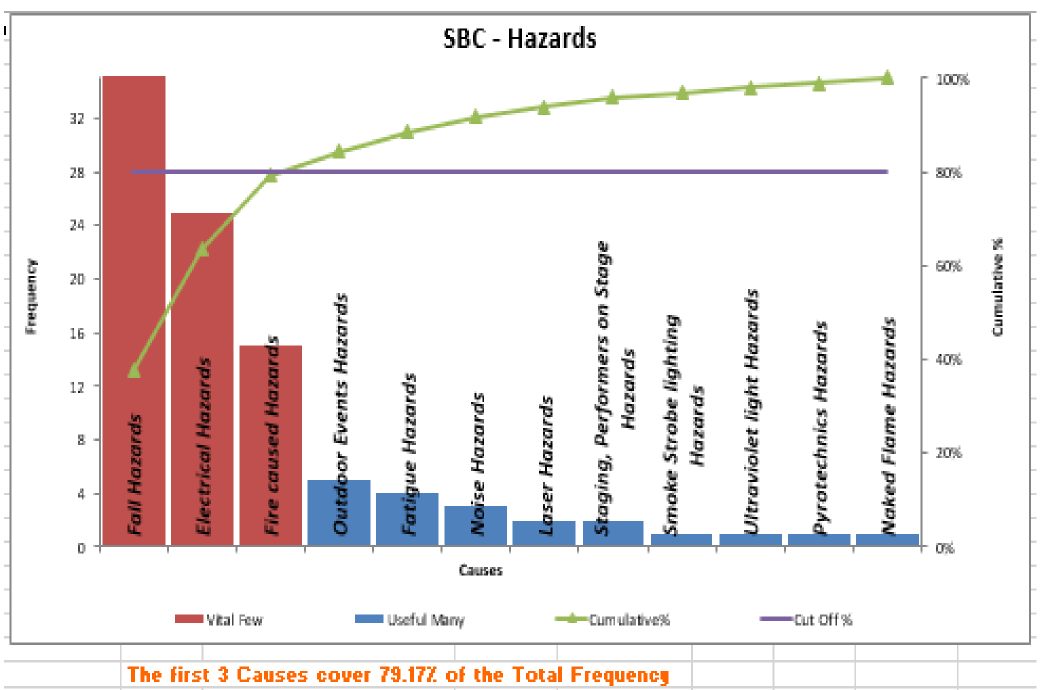


Figure 4-1 Pareto diagram of reported hazards

The Pareto chart visualises (via the horizontal purple line) how approximately 80% of accidents result from approximately 20% (falls, electrical, and fire hazards) of the reported hazards. The researcher then updated the table of reported hazards to reflect the Pareto cumulative percentages using 80% as the selection cut-off for the "vital few" hazards for further analysis.

Table 4-2 Accident number record for hazards and their cumulative percentage

Type of Hazard	Occurrence Frequency	Cumulative %
Fall Hazards	36	37.5%
Electrical Hazards	25	63.5%
Fire caused Hazards	15	79.2%
Outdoor Events Hazards	5	84.4%
Fatigue Hazards	4	88.5%
Noise Hazards	3	91.7%
Laser Hazards	2	93.8%
Staging, Performers on Stage Hazards	2	95.8%
Smoke Strobe lighting Hazards	1	96.9%
Ultraviolet light Hazards	1	97.9%
Pyrotechnics Hazards	1	99.0%
Naked Flame Hazards	1	100%
Total Frequency	96	

However, one of the disadvantages of the Pareto chart is that it provides no insight into the root causes of the reported hazards. Therefore, cause and effect analysis (also known as Fishbone Diagrams) was used to determine the most basic reasons for the hazards selected through the Pareto chart analysis. The cause-and-effect analysis, which combines brainstorming with a type of mind map, pushes problem solvers to consider all possible causes of a problem, rather than just the most obvious. The cause-and-effect analysis is discussed later in section 4.3 of this chapter.

4.2.3 Value Steam Mapping of the Current Situation

Value stream mapping is a Lean-management method for analysing the current state and designing a future state for the series of events required to provide a product or service to customers. As a matter of fact, VSMs provide a powerful visualisation of all actions required to deliver a service or a product. Hence, a VSM provides a big picture perspective to facilitate improvement to the whole process instead of the optimisation of only a limited portion. For instance, a VSM for the current state of 'decor preparation', see Figure 4-2, shows a total time of 23 minutes (the value-added time (17 minutes) and non-value-added time (6 minutes)), including steps that consume more time and are candidates for improvement.

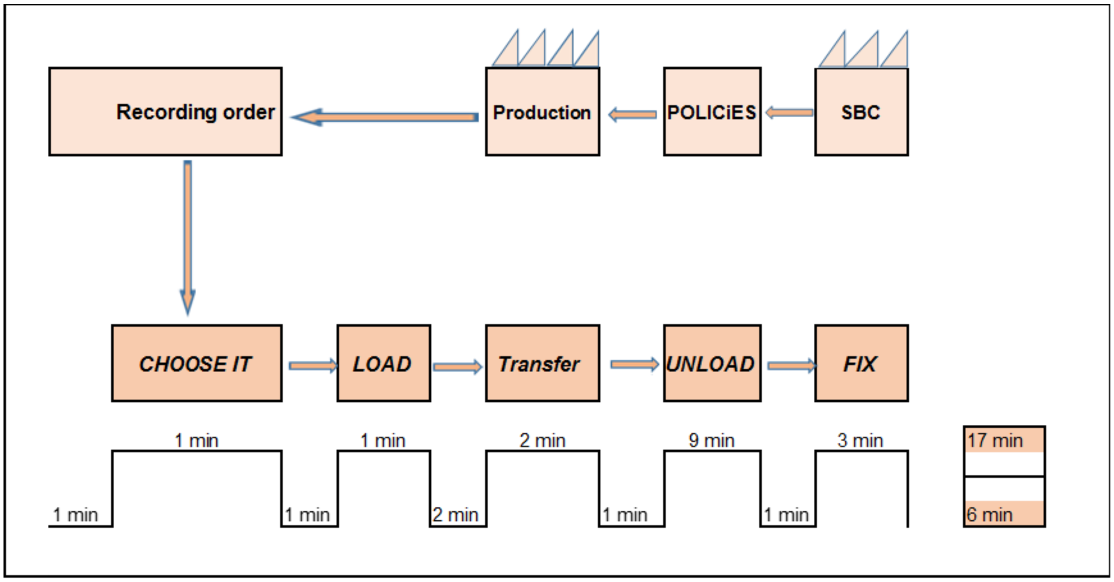


Figure 4-2 Decor preparation, current state,VSM, Worst case scenario

4.3 DMAIC Analysis Phase

In analysing the Saudi Broadcasting Corporation, as discussed above, cause-and-effect analysis was used to determine the root causes of the vital few hazards, namely fall hazards, electrical hazards and fire hazards, selected by the Pareto chart analysis.

4.3.1 Cause and Effect Analysis

The main idea behind cause-and effect-analysis is a source of variation. Causes are usually grouped into major categories, such as man, measurements, environment, method, material, and machine, to identify the sources of variation.

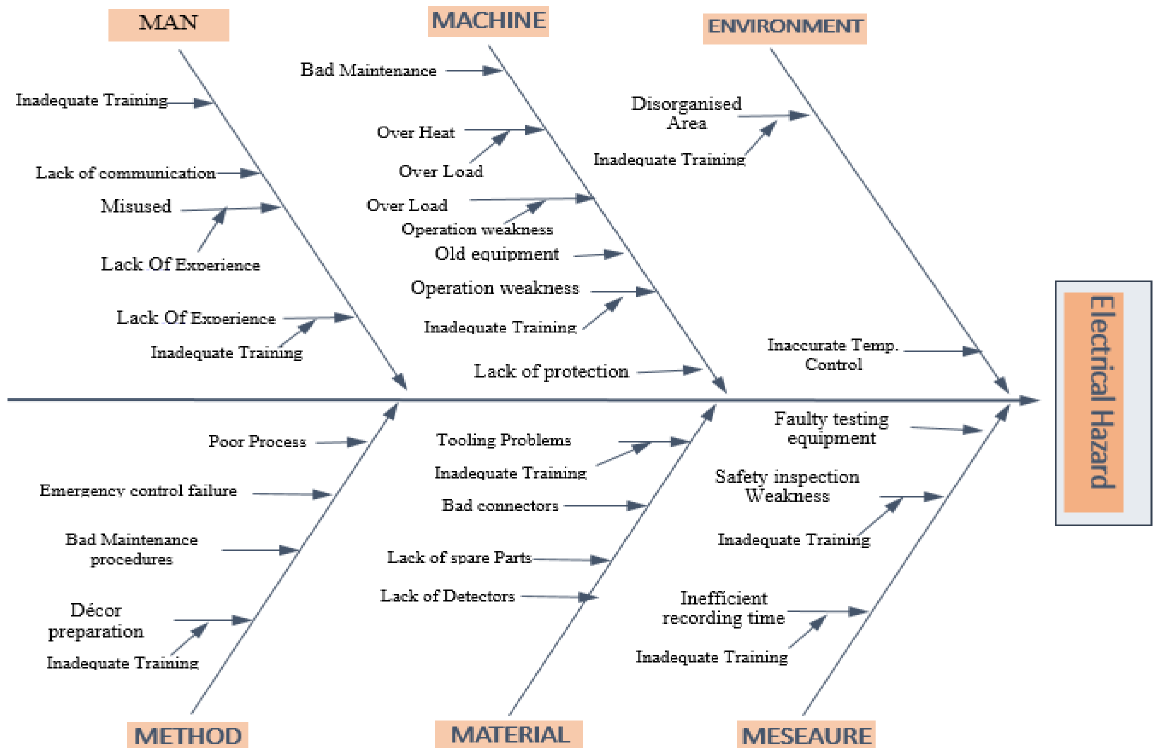


Figure 4-3 Cause-and-effect diagram of electrical hazards

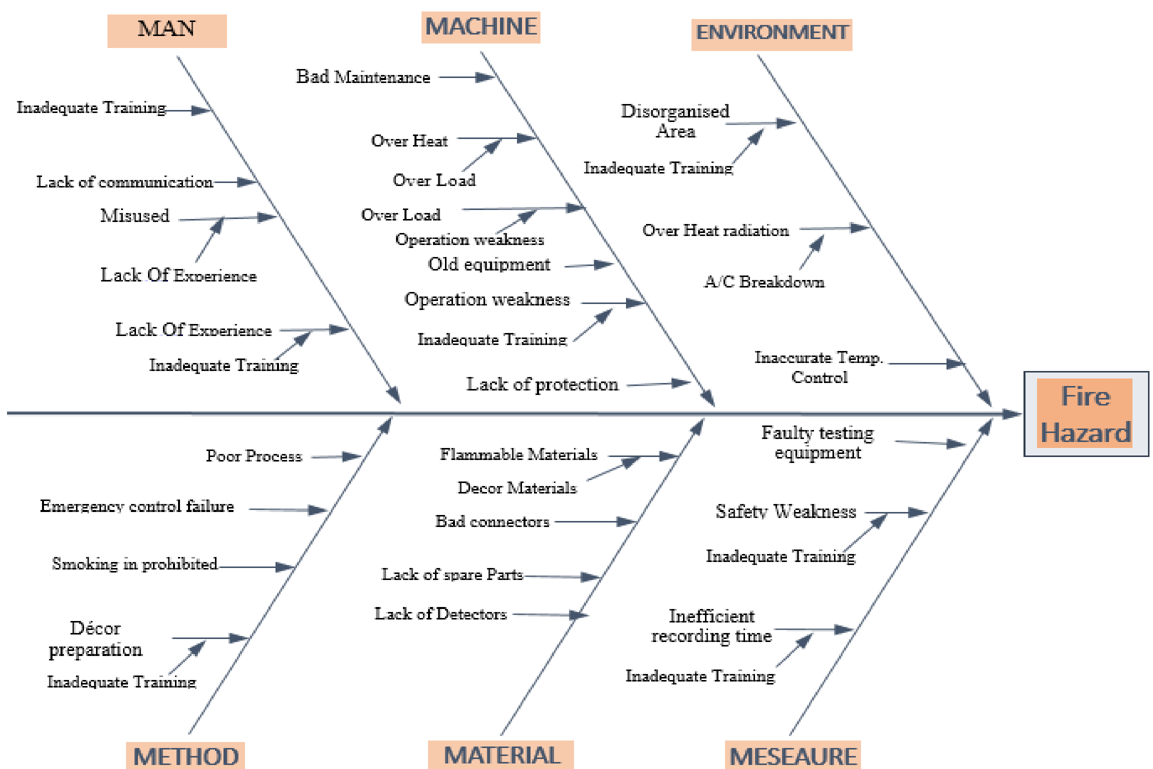


Figure 4-4 Causes and effect diagram of fire hazard

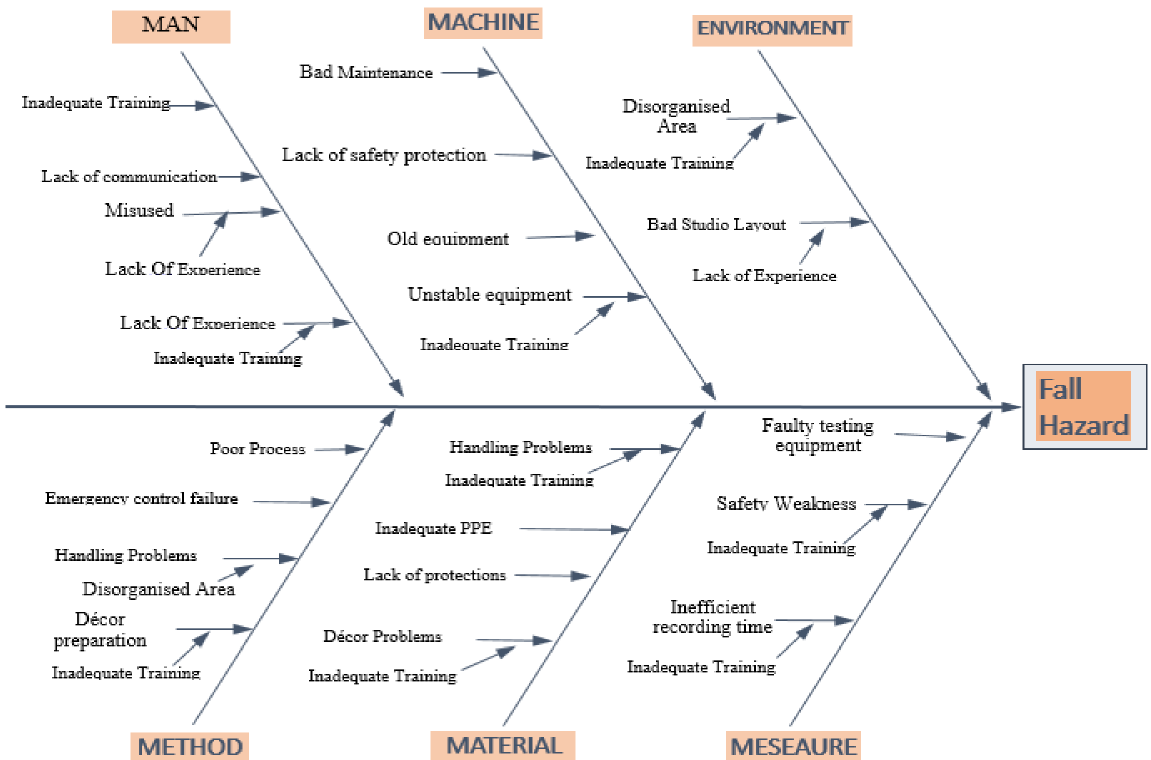


Figure 4-5 Cause and effect diagram of fall hazard

From the above cause-and-effect diagrams, it can be seen that 'Inadequate Training', 'Lack of Experience' and 'Disorganised Area' are the most frequent secondary causes having a direct effect on the work environment safety in the Saudi Broadcasting Corporation. As such, they deserve closer examination. On the other hand the fishbone diagram relies on brainstorming, which was conducted by 10 expert engineers (Electrical, Mechanical, Décor and Safety engineers) in SBC, and does not aid in prioritisation. Therefore, a failure mode and effects analysis (FMEA) was conducted to clarify prioritisation of failures of high severity, occurrence, and low detection.

4.3.2 Failure Mode Effect Analysis

After the analysis of the root causes of each hazard, a FMEA was conducted to identify potential failure modes based on employees' experience with similar systems. This process serves as a form of design review in an attempt to mitigate process weaknesses.

Table 4.6 shows the FMEA of the three hazards, electrical, fire, and falling. In this analysis, the potential failure modes, potential failure effects, and potential causes are all detailed. In conducting the FMEA, three steps were followed:

Step 1: A team listed failure modes and causes for each step in the process. They listed all possible “failure modes” – that is, anything that could go wrong, including minor and rare problems. Then, for each failure mode listed, the team identified all the possible causes.

Step 2: For each failure mode, the team assigned a numeric value for likelihood of occurrence, likelihood of detection, and severity.

The assigned values were then used to calculate the risk priority numbers (RPNs). RPNs are used to prioritise areas of focus and aid in assessing opportunities for improvement. For every failure mode identified, the team answered the following questions and assigned the appropriate score. Team consensus was reached and is presented in Tables 4.3, 4.4 and 4.5.

Likelihood of occurrence: How likely is it that this failure mode will occur?

The team assigned a score from a scale of 1 through 10, where 1 indicates “very unlikely to occur” and 10 indicates “very likely to occur.”

Likelihood of detection: If this failure mode occurs, how likely is it that the failure will be detected?

The team assigned a score from a scale of 1 through 10, where 1 indicates “very likely to be detected” and 10 indicates “very unlikely to be detected.”

Severity: If this failure mode occurs, how serious is it that harm will occur?

The team assigned a score from a scale of 1 through 10, where 1 indicates “very little harm will occur” and 10 indicates “very severe harm will occur.”

Step 3: Evaluate the results.

To calculate the RPN for each failure mode, the three scores (a value of 1 through 10 for each of likelihood of occurrence, detection, and severity) were multiplied. It is worth noting that the lowest possible score will be 1 and the highest 1,000. See Table 4.6 for all calculated

RPNs. The failure modes with the top 3 highest RPNs, namely: fall, electrical, and fire hazards, were prioritised as the first targets for improvement opportunities.

Table 4-3 Severity

Severity Evaluation Criteria		
Effect	**Criteria: Severity of Effect**	**Rank**
Hazardous - without warning	Very high severity ranking when a potential failure mode affects safe operation and/or involves noncompliance with government regulation without warning.	10
Hazardous - with warning	Very high severity ranking when a potential failure mode affects safe operation and/or involves noncompliance with government regulation with warning.	9
Very high	Equipment inoperable, with loss of primary function.	8
High	Equipment operable, but at reduced level of performance. Customer or employee dissatisfied.	7
Moderate	Equipment operable, but some item(s) inoperable. Customer or employee experiences discomfort.	6
Low	Equipment operable, but some item(s) operable at reduced level of performance. Customer or employee experiences some dissatisfaction.	5
Very low	Production results do not conform. Defects noticeable by average customers.	4
Minor	Production results do not conform. Defects noticeable by most customers.	3
Very minor	Production results do not conform. Defects noticeable by discriminating customers.	2
None	No effect.	1*
*Note: Zero (0) rankings for Severity, Occurrence or Detection are not allowed		

Table 4-4 Occurence

Suggested Occurrence Evaluation Criteria			
Rank	**CPK**	**Failure Rates**	**Probability of Failure**
10	> 0.33	> 1 in 2	Very High: Failure almost inevitable
9	> 0.33	1 in 3	
8	> 0.51	1 in 8	High: Repeated failures
7	> 0.67	1 in 20	
6	> 0.83	1 in 80	Moderate: Occasional failures
5	> 1.00	1 in 400	
4	> 1.17	1 in 2000	
3	> 1.33	1 in 15 000	Low: Relatively few failures
2	> 1.50	1 in 150 000	
1*	> 1.67	< 1 in 1 500 000	Remote: Failure is unlikely
*Note: Zero (0) rankings for Severity, Occurrence or Detection are not allowed			

Table 4-5 Detection

Suggested Detection Evaluation Criteria		
Detection	**Criteria**	**Rank**
Absolute Uncertainty	Design control will not and/or cannot detect a potential cause/ mechanism and subsequent failure mode; or there is no design control.	10
Very Remote	Very remote chance the design control will detect a potential cause/mechanism and subsequent failure mode.	9
Remote	Remote chance the design control will detect a potential cause/ mechanism and subsequent failure mode.	8
Very Low	Very low chance the design control will detect a potential cause/ mechanism and subsequent failure mode.	7
Low	Low chance the design control will detect a potential cause/mechanism and subsequent failure mode.	6
Moderate	Moderate chance the design control will detect a potential cause/mechanism and subsequent failure mode.	5
Moderately High	Moderately high chance the design control will detect a potential cause/mechanism and subsequent failure mode.	4
High	High chance the design control will detect a potential cause/mechanism and subsequent failure mode.	3
Very High	Very high chance the design control will detect a potential cause/mechanism and subsequent failure mode.	2
Almost Certain	Design controls will almost certainly detect a potential cause/mechanism and subsequent failure mode.	1*
*Note: Zero (0) rankings for Severity, Occurrence or Detection are not allowed		

Table 4-6 Failure mode and effect analysis

Hazard	Process	Potential Failure Mode	Potential Failure Causes	Potential Failure Effects	Current				Action Taken
					Severity	Occurrence	Detection	RPN	
Electric	Lighting adjustment	Wrong angles	Lack of experience,	Fuzzy pictures (un clear)	8	6	7	33 6	Appropriate Training. Applying Poke-Yoka
	Décor preparation	Bad Connection	Inadequate training	Electrical shock	8	7	7	39 2	Appropriate training and applying VSM, 5S and Poka-Yoke
	Electrical connections	Overheating	Using Bad connectors	Equipment damage	8	5	7	28 0	Regular inspection, monitoring, and appropriate training
	Recording	Overload	Inadequate training	Equipment damage	8	6	8	38 4	Appropriate Training
Fire	Recording	Overheating	Inadequate insulation	Ignite Fire	8	5	6	24 0	Regular safety inspection
	Lighting adjusting	heating up to flammable limit	Lack of experience & bad connectors	Ignite fire	8	6	6	28 8	Regular safety inspection and training
	Safety inspection	alarm failure	Inadequate training & Bad maintenance	Does not provide fire detection	8	7	7	39 2	Appropriate training and proper

Hazard	Process	Potential Failure Mode	Potential Failure Causes	Potential Failure Effects	Current				Action Taken
					Severity	Occurrence	Detection	RPN	
									maintenance programme.
Fall	Work organising	Falling Equipment	Disorganised area	Destroy decoration objects	7	7	7	343	5S
	Lifting equipment	Workers Fall	Inadequate training, and lack of experience	fatal injuries	7	7	7	343	Provide intensive safety training
	Decoration Preparation	Falling walls	Wall not assembled properly (Decor problems)	Equipment damages	7	6	7	294	Provide intensive training

Table 4.6 summarises failure modes, the potential cause of failure, and the effect of each failure for each of the risks. It also shows the severity, occurrence, and detection raking and RPN number which indicate the overall importance of each failure mode.

The Highest RPN for the electrical, fire and fall hazards are 392, 392 and 343, respectively.

Table 4-7 Combined hazards' root causes, 28 Dec. 2011

Causes	RPN				
	Electrical Hazards	Fire Hazards	Fall Hazards	Quadrature sum	Combined value
Inadequate training	392	392	343	424,977	652
Lack of experience	336	288	343	313,489	560
Disorganised area			343	117,649	343

Here, the RPN values of the three hazard root causes were considered with regard to the vital few results selected using Pareto analysis for the FMEA sheets.

These values were combined using the square root of the sum of the original values' square to demonstrate the most important root causes to be controlled. Referring to the FMEA table above, inadequate training, lack of experience, disorganised area, and décor problems are selected as the first priority for consideration for the Occupational Health and Safety Management System (OHSMS)/Lean Six Sigma (LSS) intervention in the media industry.

The Highest RPN for the electrical, fire and fall hazards are 392, 392 and 343, respectively.

Subsequently, a second Pareto chart analysis was conducted to analyse the root causes affecting fall, electrical and fire hazards.

4.3.3 Pareto Chart, Electrical, Fire, and Fall Hazards

Based on accident records provided by the TV studios in Riyadh (Saudi Broadcasting Corporation) in December 2011, Pareto charts were developed for each of electrical, fire, and fall hazards. The resulting charts are presented below.

The first four causes of electrical hazards, inadequate training, lack of experience, overload, and disorganised area, account for about 80.0% of the total frequency.

Table 4-8 Causes of electrical hazards and their cumulative percentages

Root Cause Description	Frequency	Cumulative %
Inadequate training	8	32.0%
Lack of experience	4	48.0%
Overload	4	64.0%
Disorganised area	3	76.0%
Bad maintenance	2	84.0%
Overheating	2	92.0%
Old equipment	1	96.0%
Using bad connectors	1	100.0%
Total Frequency	25	

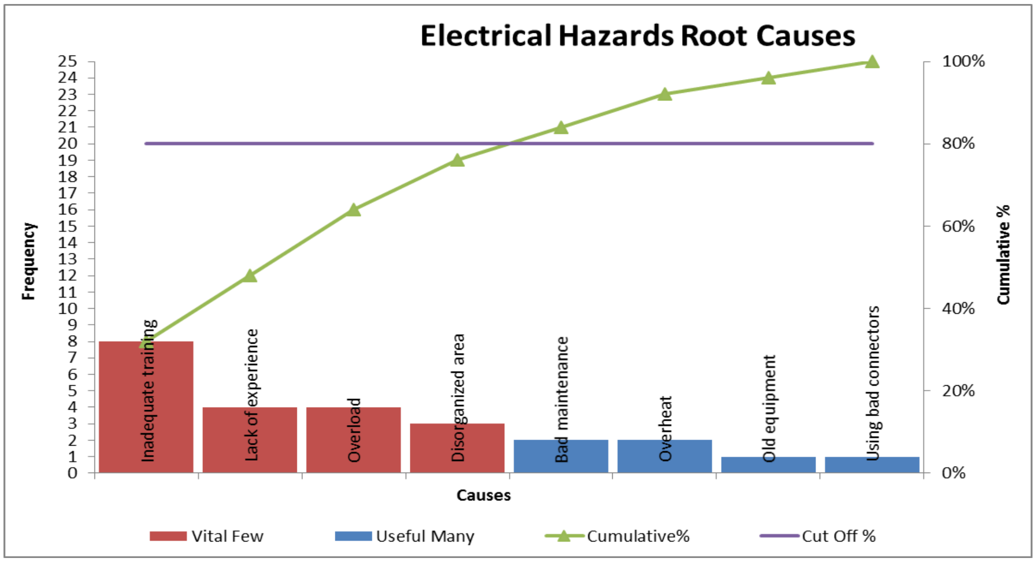


Figure 4-6 Pareto chart analysis for electrical hazards' root causes

The first five causes of fire hazards, inadequate training, lack of experience, overheating, using flammable materials, and disorganised area, account for 80.0% of the total frequency.

Table 4-9 Causes of fire hazards and their cumulative percentages

Root Cause Description	Frequency	Cumulative %
Inadequate training	4	27%
Lack of experience	3	47%
Overheating	2	60%
Using flammable materials	2	73%
Disorganised area	1	80%
Using bad connectors	1	87%
Lack of protection	1	93%
Lack of detection	1	100%
Total Frequency	15	

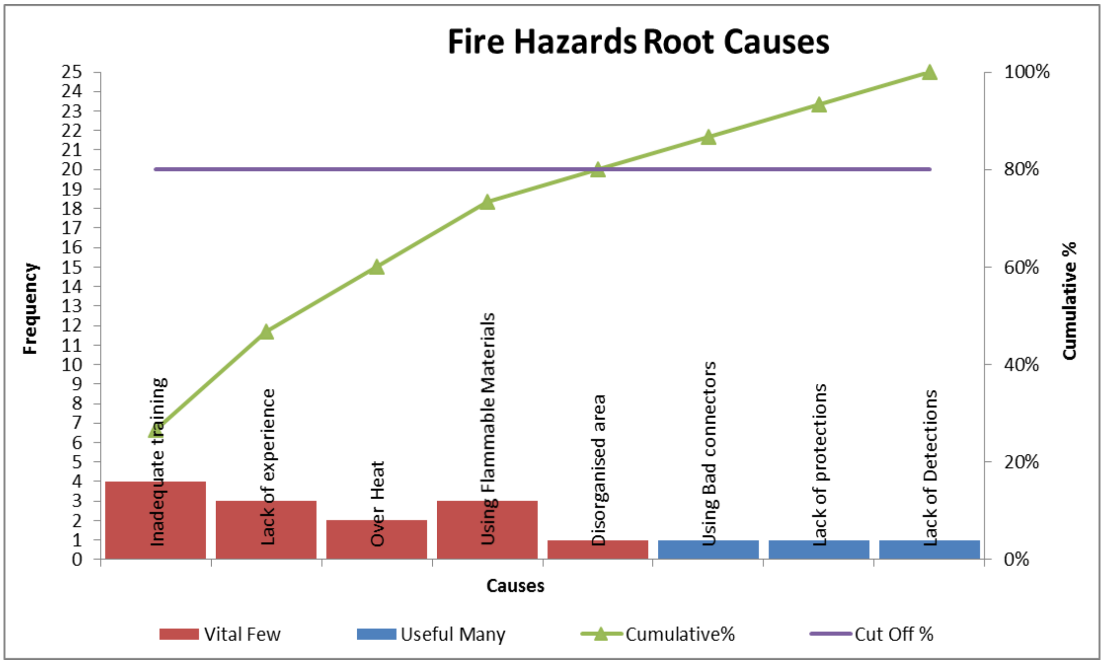


Figure 4-7 Pareto chart analysis for fire hazards' root causes

The first three causes of fall hazards, which are inadequate training, lack of experience, disorganised area and décor problem/bad maintenance, account for about 80.0% of the total frequency.

Table 4-10 Causes of fall hazards and their cumulative percentages

Root Cause Description	**Frequency**	**Cumulative %**
Inadequate training	13	36.1%
Lack of experience	8	58.3%
Disorganised area	7	77.8%
Décor problem	3	86.1%
Handling problems	2	91.7%
Tooling problems	1	94.4%
Bad maintenance	1	97.2%
Safety Weakness	1	100.0%
Total Frequency	36	

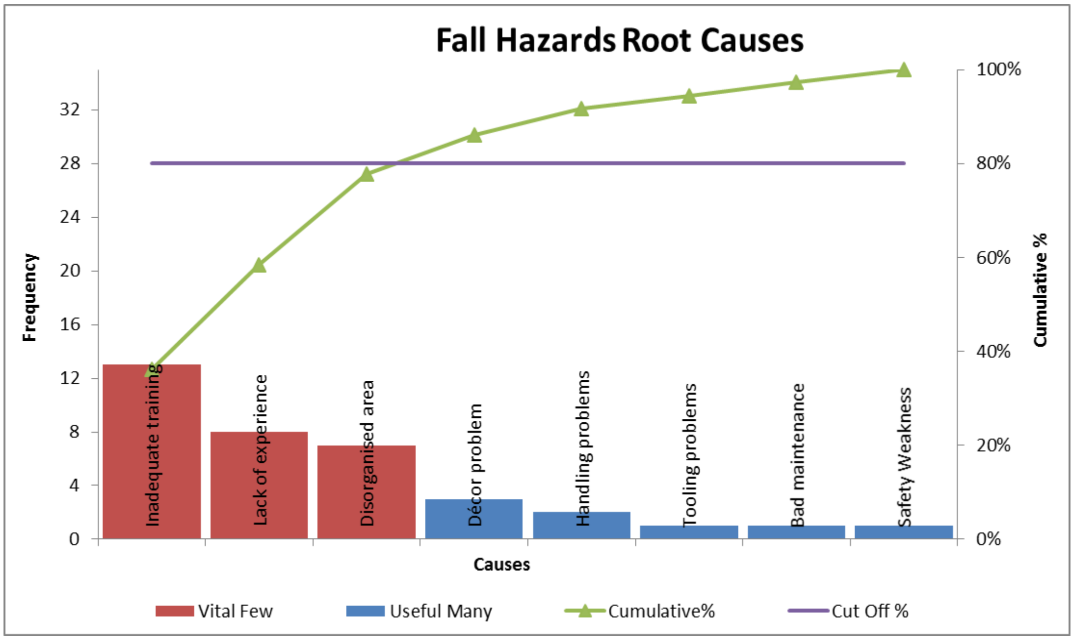


Figure 4-8 Pareto chart analysis for fall hazards' root causes

4.3.4 Bayesian Belief Networks

Bayesian Belief Networks provide a mathematically correct and therefore more precise method of measuring the effects of events on each other. The formulas involved also allow calculations in both directions. It could be determined which event was the most likely cause of another event. Assessment of the current situation was conducted using MSBNx.

4.3.4.1 Electrical Hazard BBN Assessment

The collected data was populated into the conditional probability Table 4.11 to represent the relationship of the variables InaT, LE, DA, and B_Con. Table 4.11 shows the conditional probabilities for InaT, LE, DA, and B_Con. As an example, from Table 4.11, the variable InaT corresponding to B_Con has a probability of 0.968 for the first state "Yes" and 0.032 for the second state "No." As mentioned above, a complete conditional probability table for the electrical-caused hazards is shown in Appendix D.

Table 4-11 Tabulated conditional probability table for InaT, LE, DA and B_Con

InaT	LE	DA	B_Con Yes	B_Con No	Total
Yes	Yes	Yes	.968 (30/31)	.032(1/31)	31
		No	0 (0/4)	1 (4/4)	4
	No	Yes	1 (1/1)	0 (0/1)	1
		No	0 (0/9)	1 (9/9)	9
No	Yes	Yes	1 (2/2)	0 (0/2)	2
		No	0 (0/1)	1 (1/1)	1
	No	Yes	1 (1/1)	0 (0/1)	1
		No	0 (0/1)	1 (1/1)	1
Total			34	16	50

Parent Node(s)			B_Con		
InaT	LE	DA	Yes	No	bar charts
Yes	Yes	Yes	0.968	0.032	
		No	0.0	1.0	
	No	Yes	1.0	0.0	
		No	0.0	1.0	
No	Yes	Yes	1.0	0.0	
		No	0.0	1.0	
	No	Yes	1.0	0.0	
		No	0.0	1.0	

The complete representation of the Electrical Hazard BBN is shown in Figure 4-9 below:

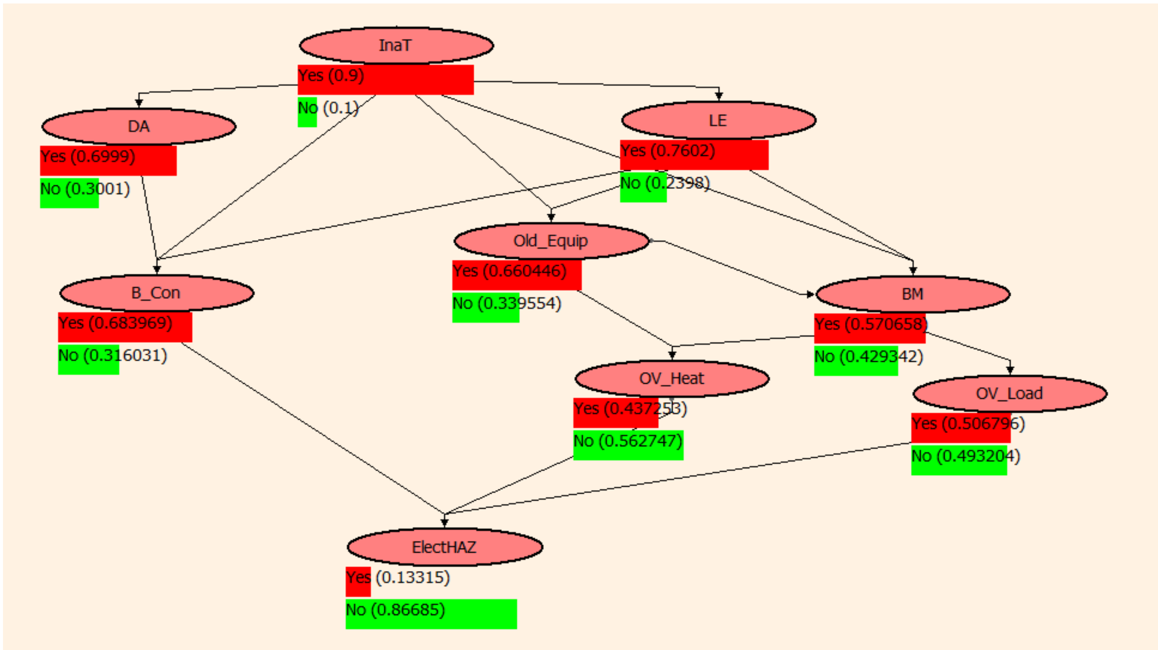


Figure 4-9 A BBN network for electrical hazard assessment of the current situation with states of conditional probabilities

As can be seen in Figure 4.9, in the current situation, the probability of occurrence of the main and sub causes is very high in most of the identified causes. For example, there is a probability of 90% of the occurrence of inadequate training, 76% of the occurrence of lack of experience, and 70% of the occurrence of a disorganised area. The resulting overall probability of the occurrences of electrical hazards in the current situation is 13.3%.

Sensitivity analysis provides a method to determine how different probability values of an independent variable will impact a particular dependent variable under a given set of assumptions. Therefore, the researcher used sensitivity analysis in order to project and compare the potential influence of improvement among selected root causes.

Electrical Hazard Sensitivity Analysis 1: Mitigation of lack of experience (LE) (to a probability of 0.00).

In this sensitivity analysis, lack of experience is assigned the probability of 0.00 (implying that lack of experience is never a causal factor), and the probability of Electrical Hazard is observed. Figure 4-10 shows the updated conditional probability values in the BBN under these conditions.

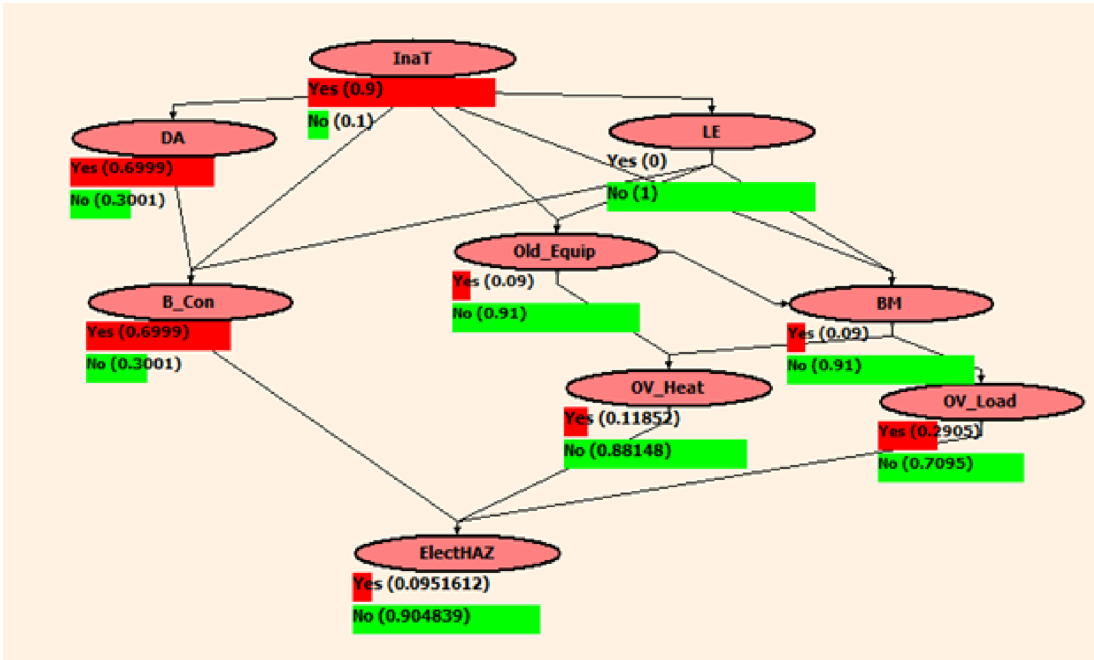


Figure 4-10 A BBN network of electrical hazards where LE is fully mitigated

Based on Figure 4-10, full mitigation of lack of experience causality (probability adjusted to 0.00) resulted in 28.6% decrease in the probability of electrical hazards from 13.3% to 9.5%.

Electrical Hazard Sensitivity Analysis 2: Mitigation of disorganised area (DA) (to a probability of 0.00).

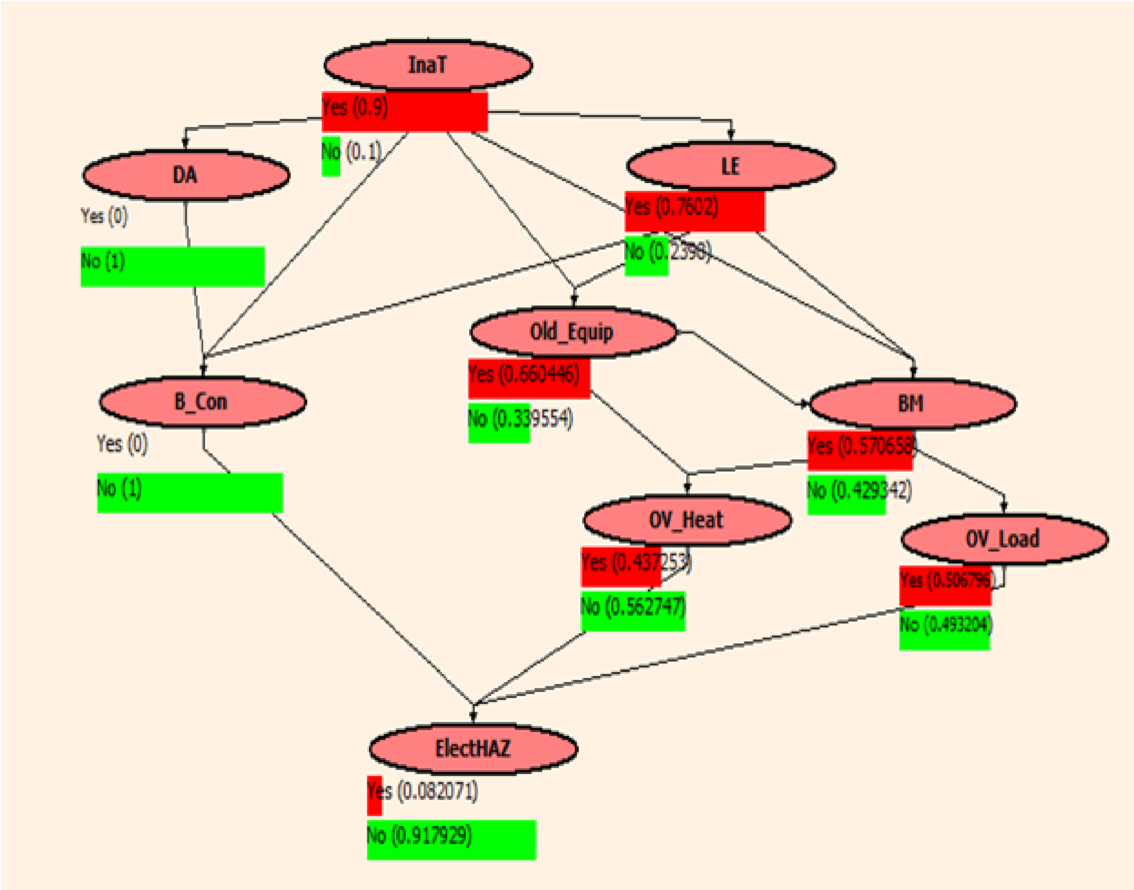


Figure 4-11 A BBN network of electrical hazards where DA is fully mitigated

Based on Figure 4-11, when disorganised area probability is adjusted to 0.00 (implying full mitigation of disorganised area causality) the probability of electrical hazards decreased by 38.3% from 13.3% to 8.2%. Therefore, intervention in the three variable DA causes has the potential to contribute significantly to minimising electrical hazards.

4.3.4.2 Fire Hazard BBN Assessment

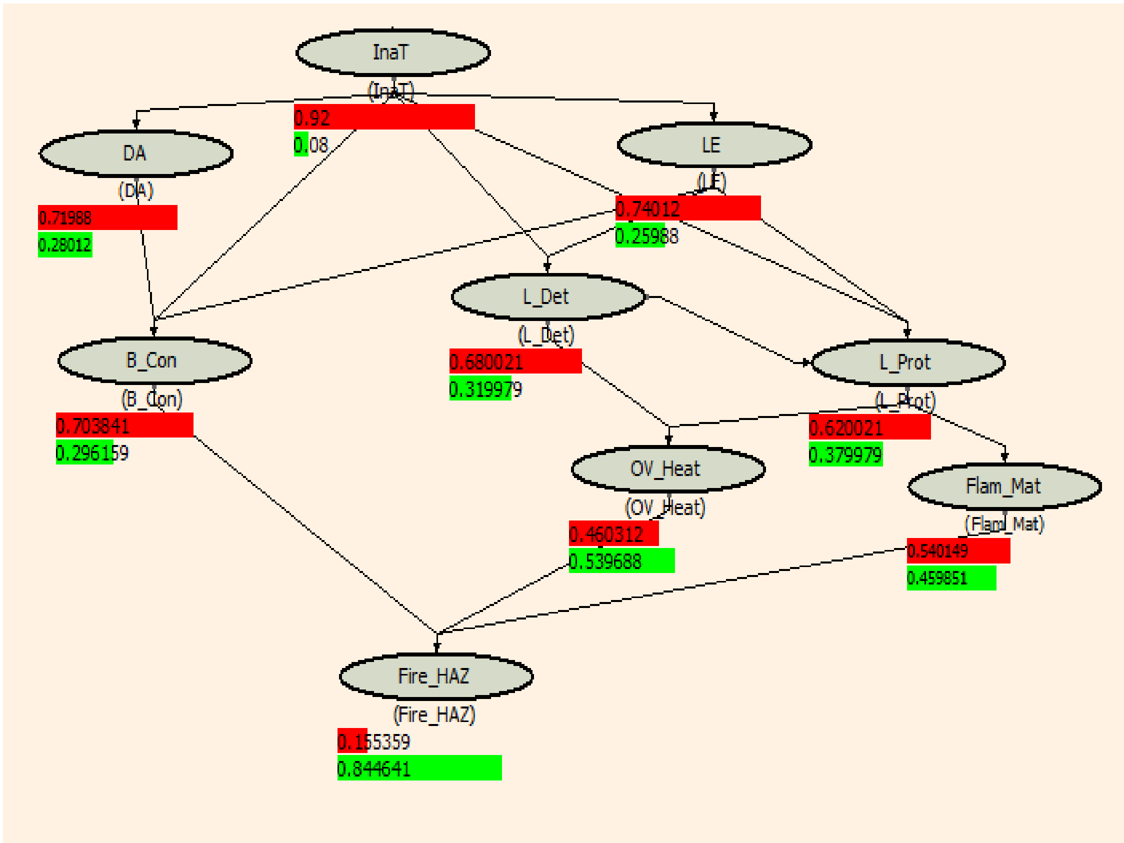


Figure 4-12 A BBN network for fire hazard assessment of current situation with states of conditional probabilities

As can be seen in Figure 4-12, in the current situation, the probability of occurrence of the main and sub causes is very high in most of the causes. For example, there is a probability of 92% of the occurrence of inadequate training, 74% of occurrence of lack of experience and 72% of occurrence of disorganised area. The overall probability of the occurrences of fire hazards in the current situation is 15.5%.

4.3.4.3 Fall Hazard BBN Assessment

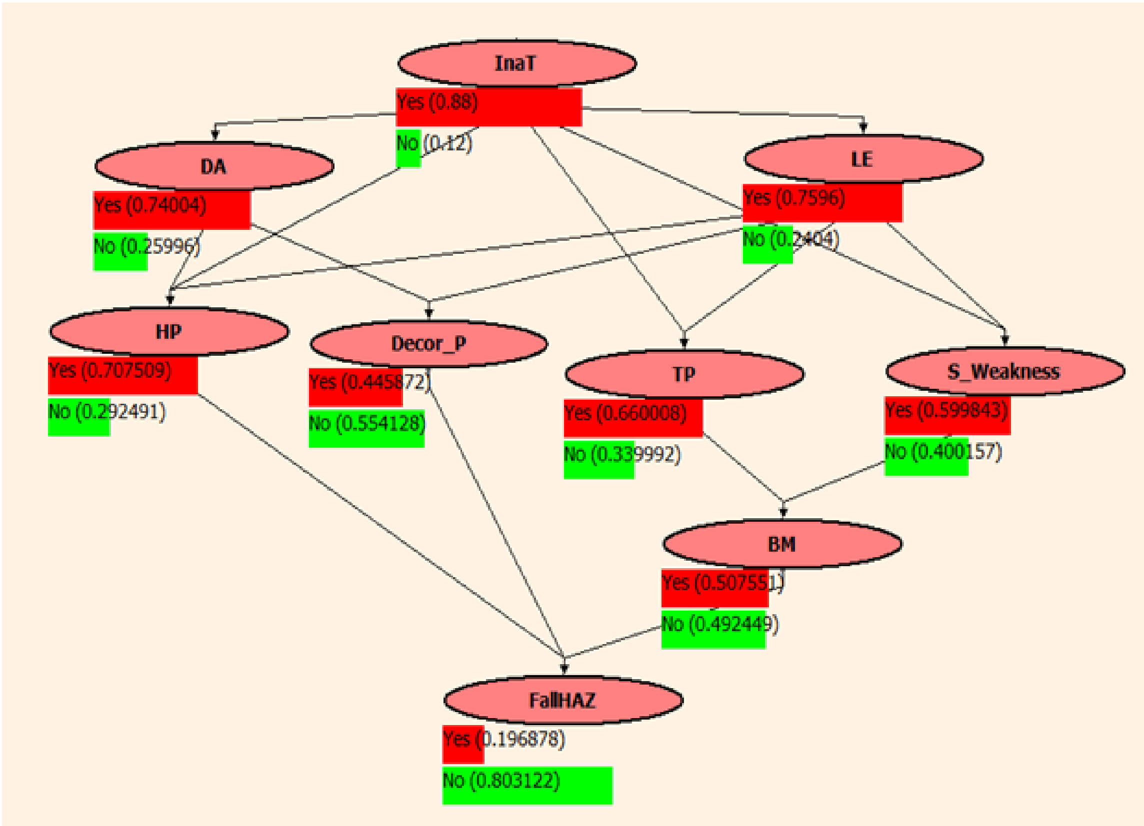


Figure 4-13 A BBN network for fall hazard assessment of the current situation with states of conditional probabilities

As can be seen in Figure 4-13, in the current situation, the probability of occurrence of the main and sub causes is very high in most of the causes. For example, there is a probability of 88% of the occurrence of inadequate training, 76% of occurrence of lack of experience and 74% of occurrence of disorganised area. The overall probability of the occurrences of fall hazards in the current situation is 19.7%.

In summary, the cause-and-effect diagrams, FMEA and BBN indicate that inadequate training and a disorganised area are potential causes in the diagrams is addressed as predicted the causes have the most significant effects on work environment safety in Saudi Broadcasting Corporation. In the next chapter, the approach is divided into two approaches.

The first approach provides a short-term LSS solution using 5S, VSM and Poka-Yoke tools. The second approach provides a long-term solution through establishment of a zero-accident culture and intensive training to improve employees’ skills and to increase employees' experience.

CHAPTER 5: IMPROVE AND CONTROL PHASE

This chapter covers the improvement and the control phases of the Lean Six Sigma DMAIC process improvement model. The knowledge learned in the Define, Measure and Analyse phases will be transferred and utilised in the improvement phase. After gaining understanding of the root causes of the electric, fire and fall hazards, the purpose is to eliminate or minimise their occurrences. The Taguchi method will be first applied to understand the significance of these causes and to identify the level necessary to minimise them. Next, 5S is used to improve the overall safety, followed by Value Stream Map application to improve process efficiency, and finally the Poka-Yoke method is applied to minimise human errors. SPC is used to verify process improvement and monitor processes in order to identify and eliminate assignable causes so as to sustain improvement.

5.1 DMAIC Improve Phase

5.1.1 Applying Taguchi method to reduce the fire hazard

The 'Improve' phase identifies sources of variations, minimises noise factors, and optimises the process to prevent fire hazards. In this section the investigation was carried out with the aid of Taguchi L16 to identify the source of fire risks in order to minimise them.

5.1.1.1 Orthogonal Array Matrix Experiment

The Taguchi Orthogonal Array L_{16} design was applied (Table 5.1) which included 5 factors and 16 runs. Columns of L16 (2**15) Array are chosen that are 1, 2, 4, 8 and 15. The L16 is a resolution III design which means the main effect is challenging with two factor interaction.

Table 5-1 L16 Orthogonal array design matrix and the experiment results

16 runs evaluating 5 factors' effects on extinguishing time and damage percentage

Run #	**Factors**					**Extinguishing Time**	**Damage percentage**
	T	X	R	G	Q	(seconds)	%
	1	2	4	8	15		
1	0	0	0	0	0	253	84
2	0	0	0	1	1	229	82
3	0	0	1	0	1	219	75
4	0	0	1	1	0	171	73
5	0	1	0	0	1	150	52
6	0	1	0	1	0	125	49
7	0	1	1	0	0	115	18
8	0	1	1	1	1	107	16
9	1	0	0	0	1	160	51
10	1	0	0	1	0	120	26
11	1	0	1	0	0	116	15
12	1	0	1	1	1	96	12
13	1	1	0	0	0	110	20
14	1	1	0	1	1	108	13
15	1	1	1	0	1	96	12
16	1	1	1	1	0	92	8

5.1.1.2 Experimental Analysis and Discussion

5.1.1.2.1 Graphical Analysis for Extinguishing Time

The main effects plot for extinguishing time (Figure 5-1) shows that extinguishing time decreases for a trained and experienced employee, and also that it decreases for a response to the alarm of less than 30 seconds. This leads to the conclusion that training, experience and response to alarm variables are significant factors, while age and qualification factors are not as significant. Qualification could be ignored and it may not be used as a factor to improve extinguishing time.

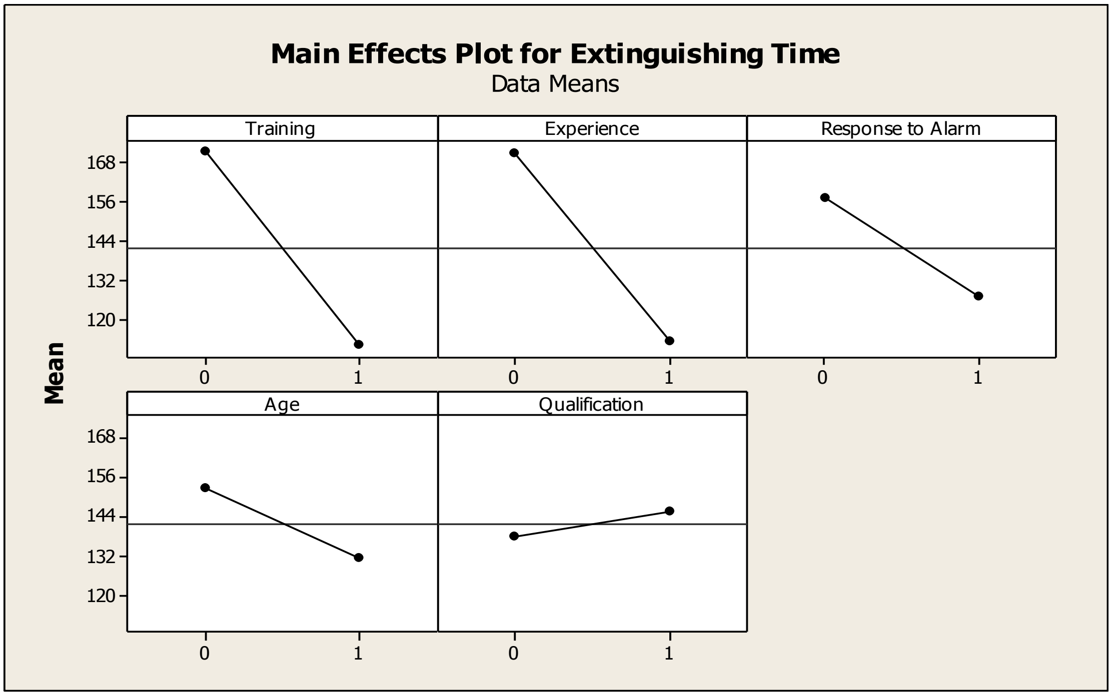


Figure 5-1 The main effect plot for extinguisher time

The interactions plot for extinguishing time (Figure 5-2) shows that there is a significant interaction between training and experience. The plot indicates that no other interaction exists. The observation focus will include the Training * Experience interaction as a term in the statistical analysis.

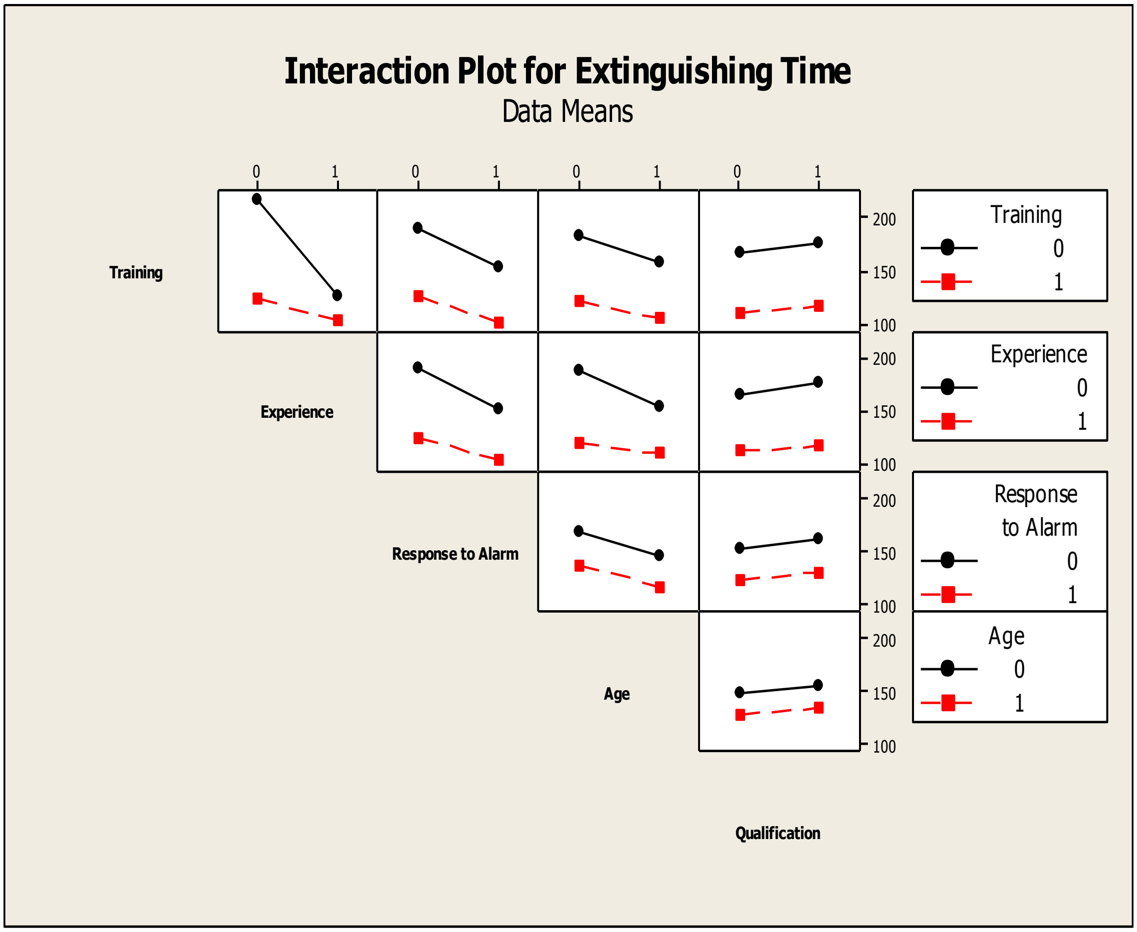


Figure 5-2 The interaction plot for extinguisher time

5.1.1.2.2 Graphical Analysis for damage percentage

The main effects plot for the percentage of damage (Figure 5-3) shows that the percentage of damage decreases for a trained and experienced employee, and also that it decreases for a response to the alarm of less than 30 seconds. This leads to the conclusion that training, experience and response to alarm variables are significant factors, while age and qualification factors are not statistically significant.

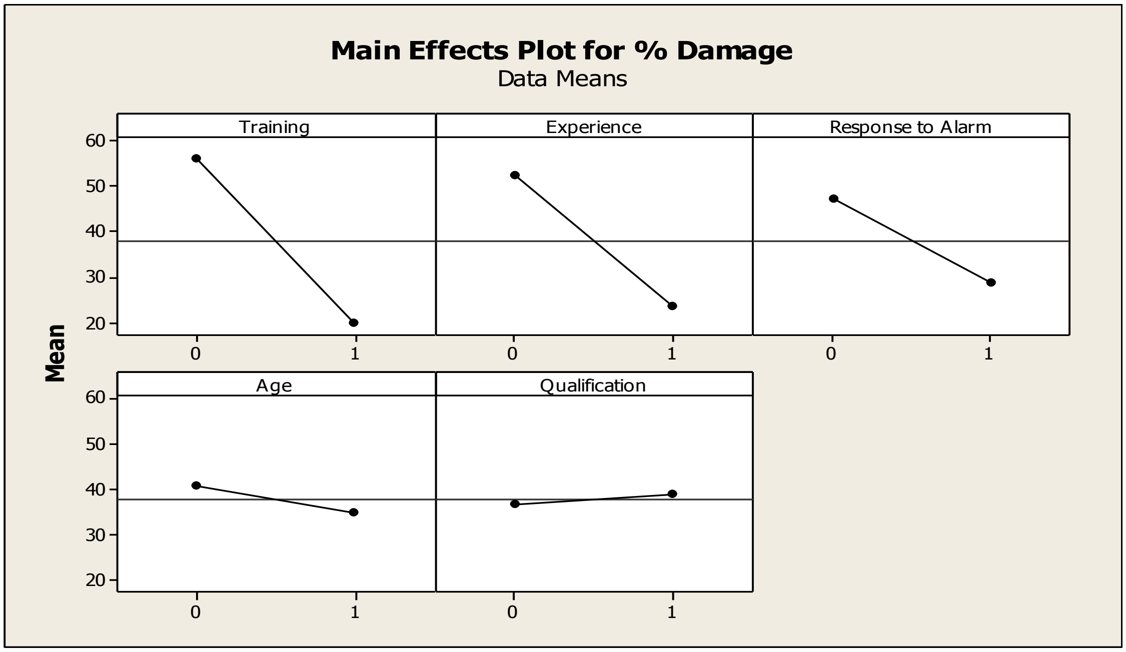


Figure 5-3 The main effects plot for damage percentage

The interaction plot in Figure 5-4 shows that there is a significant interaction between training and experience, and between age and qualification. Therefore training, experience and age qualification interactions will be utilised as terms in the statistical analysis.

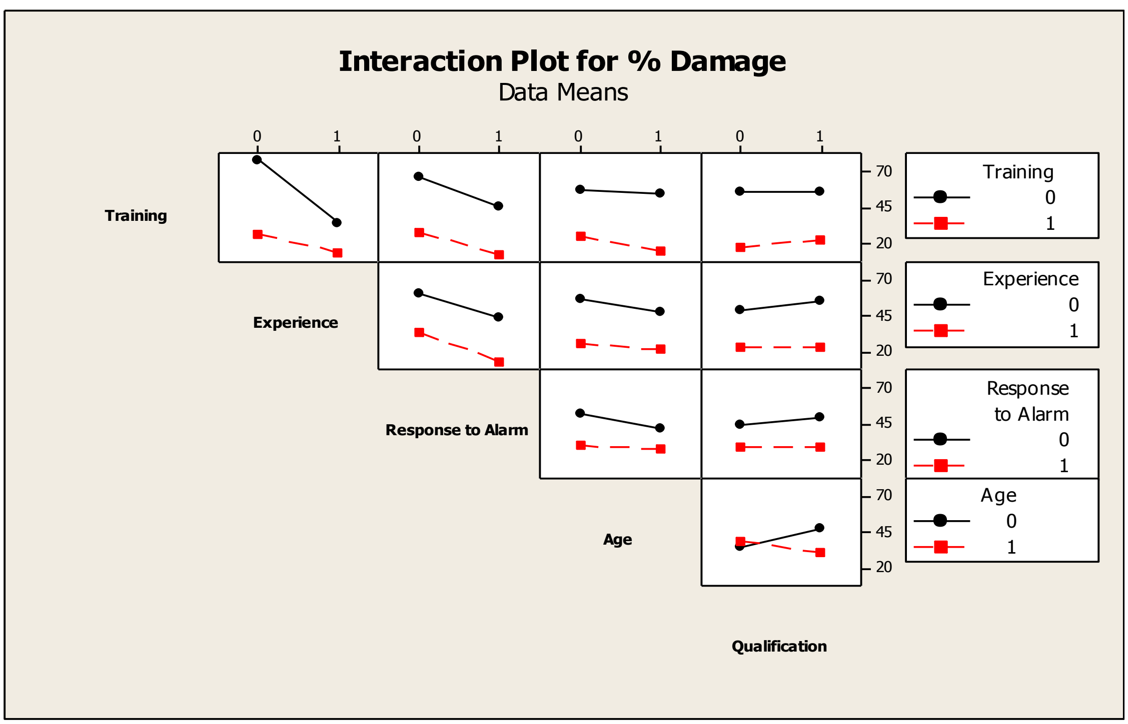


Figure 5-4 The interactions plot for damage percentage

5.1.1.2.3 Statistical Analysis for Extinguishing Time

Statistical outputs for extinguishing time are summarised in Tables 5.2 and 5.3. Regression analysis provides the coefficients for each factor and their p-values, and an analysis of variance (ANOVA) table. The order of the coefficients by absolute value indicates the relative importance of each factor to the response; the factor with the biggest coefficient has the greatest impact. The sequential sums of squares in the analysis of variance table also indicate the relative importance of each factor; the factor with the biggest sum of squares has the greatest impact.

Table 5-2 Regression analysis for extinguishing time

The regression equation is:

Extinguishing Time = 240 - 95.0 Training - 93.8 Experience - 30.4 Response to Alarm - 21.4 Age + 7.87 Qualification + 72.3 T*X

Predictor	Coef	SE Coef	T	P
Constant	239.938	7.725	31.06	0.000
Training	-95.000	8.258	-11.50	0.000
Experience	-93.750	8.258	-11.35	0.000
Response to Alarm	-30.375	5.839	-5.20	0.001
Age	-21.375	5.839	-3.66	0.005
Qualification	7.875	5.839	1.35	0.210
T*X	72.25	11.68	6.19	0.000

S = 11.6789   R-Sq = 96.9%   R-Sq(adj) = 94.8%

Table 5-3 Analysis of variance for extinguishing time

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	6	38133.9	6355.6	46.60	0.000
Residual Error	9	1227.6	136.4		
Total	15	39361.4			

Source	DF	Seq SS
Training	1	13865.1
Experience	1	13282.6
Response to Alarm	1	3690.6
Age	1	1827.6
Qualification	1	248.1
T*X	1	5220.1

The regression analysis shows that the P-value for Training, Experience, Response to Alarm, Age, and the Training*Experience interaction are 0, 0, 0.001, 0.005, and 0 respectively which are much smaller than Alpha of 0.05, indicating statistical significance, while the P-value for Qualification is 0.21 which is greater than Alpha of 0.05, indicating statistical insignificance.

The prediction equation is:

$Y_{Time} = 240 – 95X_T – 93.8X_X – 30.4X_R – 21.4X_G + 7.87 X_Q + 72.3X_TX_X$… (Equation 1)

The residual plot (Figure 10) indicates that there is no violation of the analysis of variance assumptions. The residuals are normally distributed, the residuals have equal variances, and the residuals are independent. This concludes that this model is valid.

5.1.1.2.4 Statistical Analysis for damage percentage

Statistical outputs for percentage of damage are summarised in Tables 5.4 and 5.5. The regression analysis shows that the P-value for training, experience, response to alarm, training*experience interaction, and age*qualification interaction are 0, 0, 0, 0, and 0.004 respectively which are much smaller than Alpha of 0.05, indicating statistical significance, while the P-value for age, and qualification are 0.056 and 0.379 respectively which are greater than Alpha of 0.05, indicating statistical insignificance.

Table 5-4 Regression analysis for damage percentage

The regression equation is				
% Damage = 84.1 - 52.5 Training - 44.8 Experience - 18.5 Response to Alarm + 4.75 Age + 13.3 Qualification + 32.0 T*X - 21.5 G*Q				
Predictor	Coef	SE Coef	T	P
Constant	84.125	3.793	22.18	0.000
Training	-52.500	3.793	-13.84	0.000
Experience	-44.750	3.793	-11.80	0.000
Response to Alarm	-18.500	2.682	-6.90	0.000
Age	4.750	3.793	1.25	0.246
Qualification	13.250	3.793	3.49	0.008
T*X	32.000	5.365	5.96	0.000
G*Q	-21.500	5.365	-4.01	0.004
S = 5.36482 R-Sq = 98.1% R-Sq(adj) = 96.4%				

Table 5-5 Analysis of Variance for damage percentage

Analysis of Variance					
Source	DF	SS	MS	F	P
Regression	7	11659.5	1665.6	57.87	0.000
Residual Error	8	230.2	28.8		
Total	15	11889.8			

Source	DF	Seq SS
Training	1	5329.0
Experience	1	3306.3
Response to Alarm	1	1369.0
Age	1	144.0
Qualification	1	25.0
T*X	1	1024.0
G*Q	1	462.3

The prediction equation is:

$Y_{Damage} = 84.1 – 52.5X_T – 44.8X_X – 18.5X_R + 4.75\ X_G + 13.3\ X_Q + 32X_T\ X_X – 21.5X_GX_Q$ ….. (Equation 2)

The residual plots (Figures 5-5 & 5-6) indicate that there is no violation of the analysis of variance assumptions. The residuals are non-normally distributed, the residuals have equal variances, and the residuals are independent. This concludes that the model is valid.

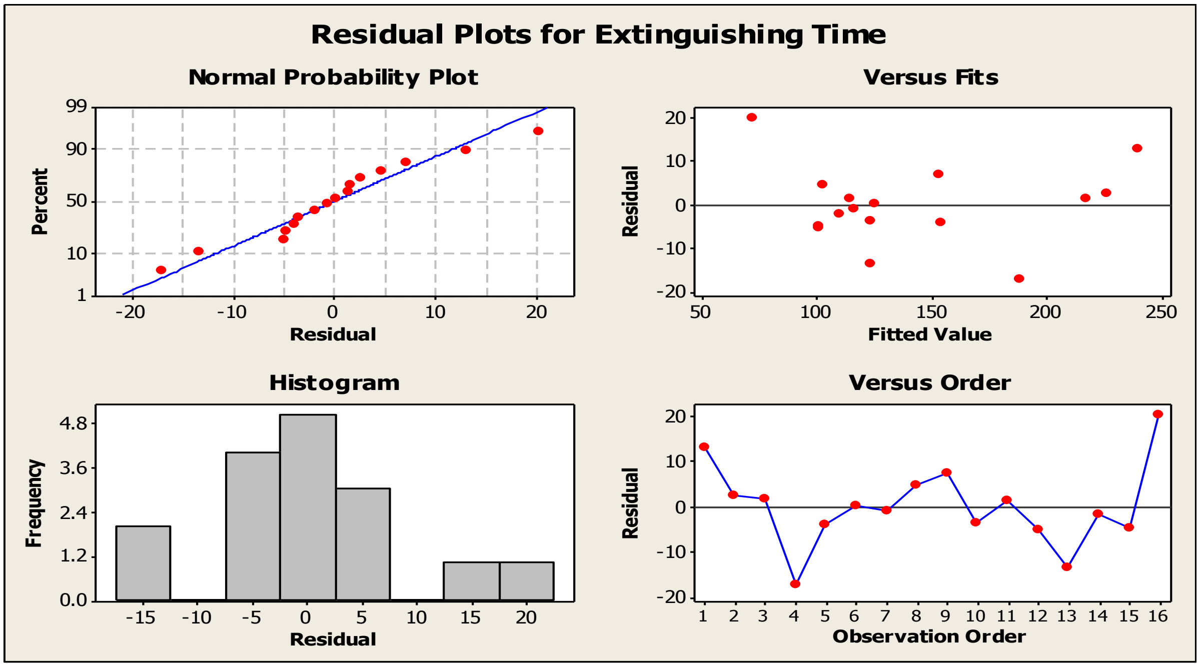


Figure 5-5 Residual analysis for extinguishing time

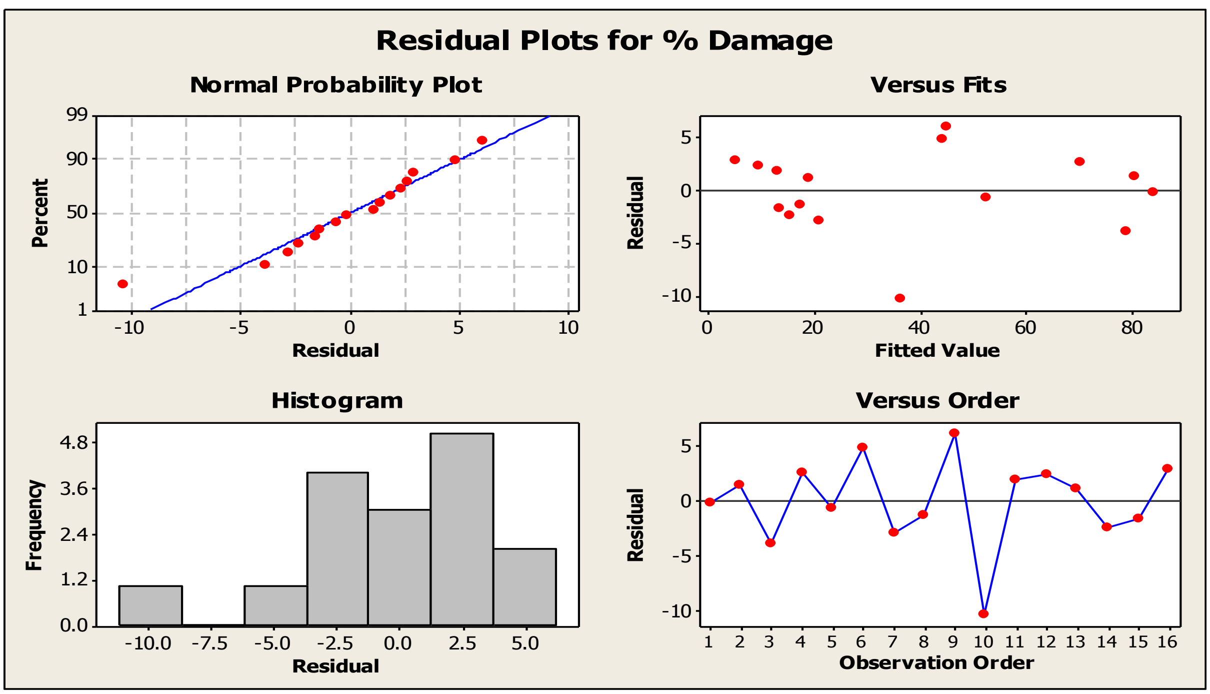


Figure 5-6 Residual analysis for percentage of damage

5.1.1.3 Relation between extinguishing time and the percentage of damage

Pearson correlation of Extinguishing Time and % Damage = 0.945 P-Value = 0.000

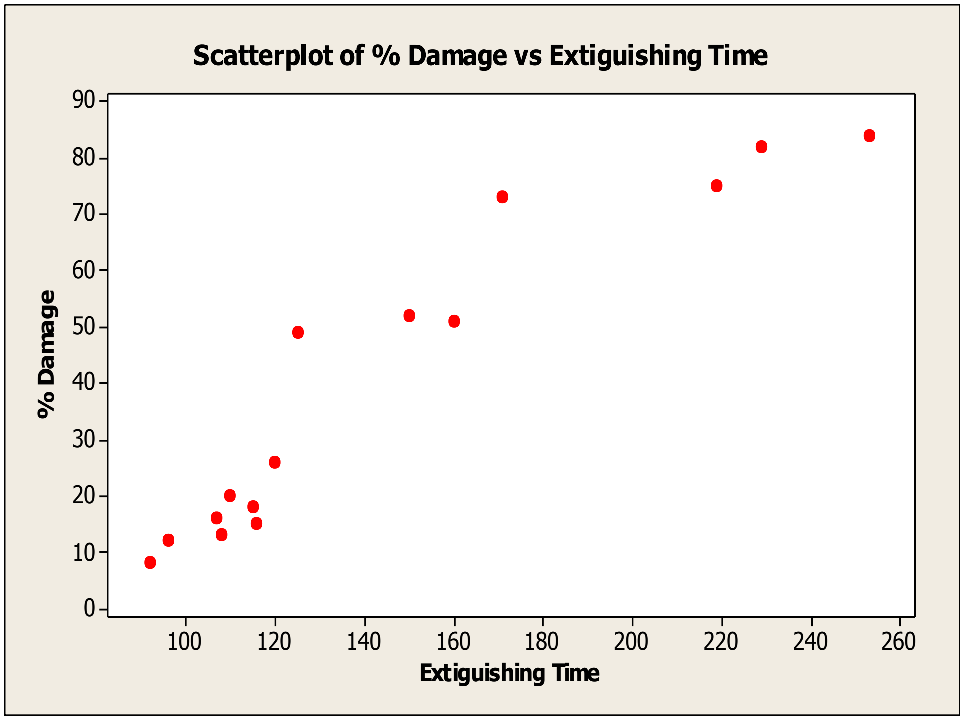


Figure 5-7 Extinguishing time vs damage percentage

Figure 5-7 clarifies the relation between the extinguishing time and the percentage of damage. It is obvious that the percentage damage increases as the extinguishing time increases. The results in the last section concluded that the training, the experience, the response to alarm and the interaction between the training and the experience have the most influence in decreasing the percentage of damage, and that the age has a small influence, and the qualification approximately has no influence.

5.1.2 Application of Lean tools

5.1.2.1 The 5S Implementation

Transferring the knowledge learned from previous sections, the team implemented 5S in the studio to minimise fire, electric, and fall hazards, and to improve overall safety. 5S implementation started with conducting training with all of the employees, outlining the objectives and the benefits of 5S. The second step was conducting a 5S audit (Appendix E) to assess the current studio conditions and to outline areas for improvements. The studio layout (Figure 5-9) was used to outline the areas that needed to be addressed. A 5S audit sheet (Figure 5-8) was used to assist the team in specifying the areas that needed to be audited, and to assess the current state of these areas with regard to 5S. Areas that scored low, areas in red or level 0, will be addressed for improvement first to bring them to level 3. Areas scored level 2 or labelled yellow will be addressed second to bring them to level three. The third step was to outline areas of improvement and to initiate corrective actions with target dates and responsibilities. The last step of the implementation is to conduct another audit to confirm the effectiveness of the corrective actions.

5S auditing checklist

AREA:					DATE:	
Manager				Supervisor		
Scoring ▼	SORT	SET IN ORDER	SHINE	STANDARDIZE	SUSTAIN	TOTAL
Total Score						
# of Questions						
Average Score						

SCORING GUIDELINES					
0	1	2	3	3.5 (4)	4.5 (5)
ZERO EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MINIMUM ACCEPTABLE LEVEL	ABOVE AVERAGE RESULTS (3 AUDITS)	OUTSTANDING RESULTS (6 AUDITS)

Category	Score	Observation	Due date	Responsible
SORT				
1. Area is free of unnecessary clutter.				
2. Only the required tools are in the work area.				
3. Only the required materials are in the work area. 4. All required Personal Protective Equipment is in work area.				
5. Area is free of slip/trip/fall hazards.				
STRAIGHTEN				
1. Locations for tools and equipment are clearly marked and labeled 2. Frequently used items are within easy reach of work area.				
3. All dormant or excess items are stored properly and out of the way.				
4. Aisles are straight, clear, and well marked.				
5. Visual controls highlight groups, work flow, equipment, & process.				
SHINE				
1. Everything in workspace is "like new"				
2. No dust or dirt anywhere.				
3. Trash and recycle bins are emptied daily				
4. No painted items are chipped or worn.				
5. All cleaning equipment is stored properly and readily available.				
STANDARDIZE				
1. Checklists for 5s activities are available and followed.				
2. Results of previous audit are posted in area.				
3. All areas for improving from previous audit are completed. 4. Last 5s assessment was performed less than a month ago. 5. All charts and metrics in the area are current.				
SUSTAIN				
1. CEO or general manager has participated in one of last 3 audits. 2. Time and resources are given to 5s activities in area				
3. Recognition is given to teams that are involved and excel in 5s activities. 4. An average score of at least 4.0 was achieved in the audits in the last 3 months.				
5. An average score of at least 4.0 was achieved in the audits in the last 6 months.				

Figure 5-8 The 5S Audit Sheet

A layout of the studio (Figure 5-9) was drawn up in December 2011; it shows the major elements in the studio which will be subjected to 5S improvements. This layout represents the worst scenario in the traditional studio before applying Lean tools.

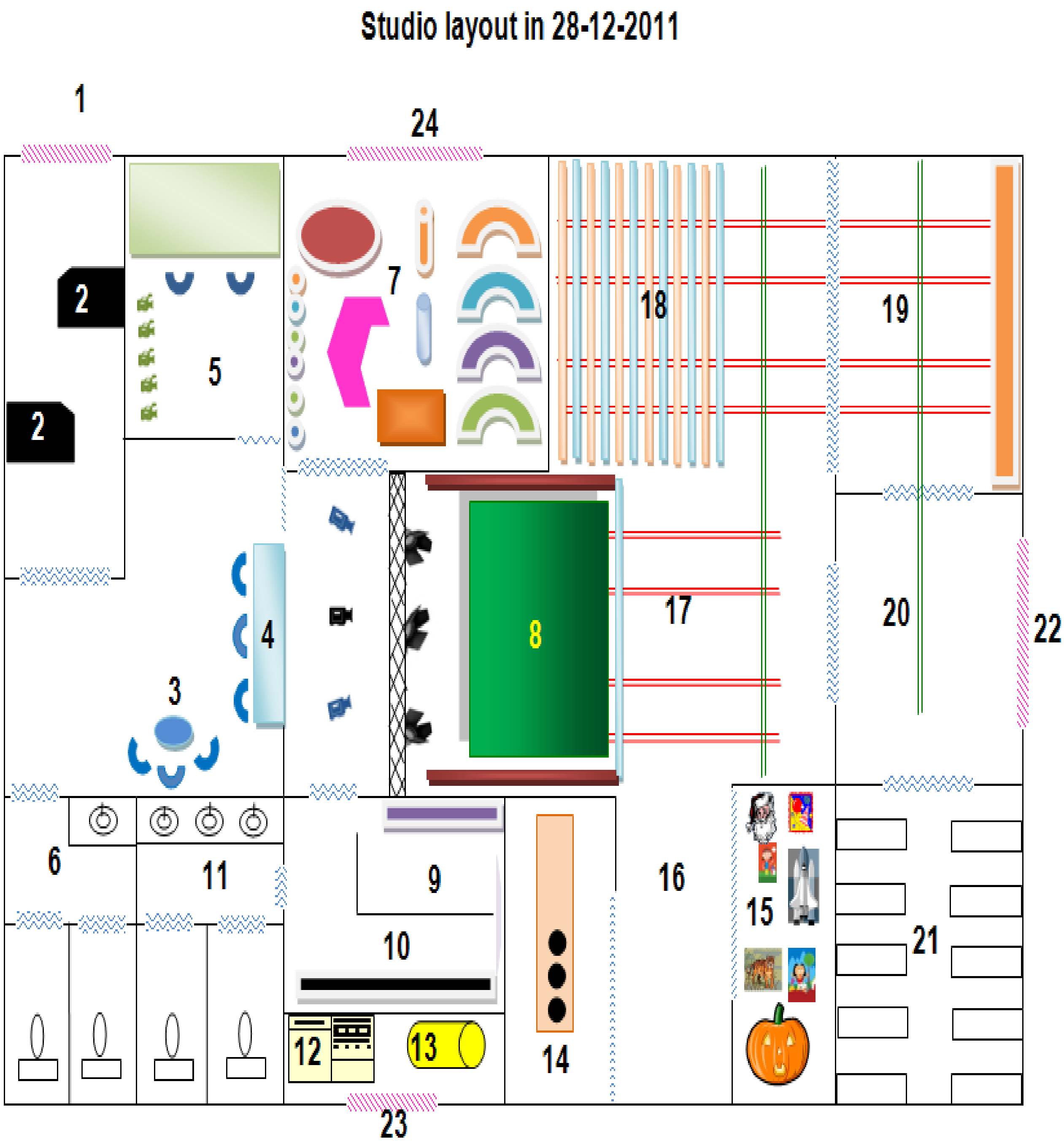


Figure 5-9 The worst scenario in the traditional studio before applying LSS

Key	Element	Details
1	Main entry	
2	Security disks	
3	Waiting area	
4	Recording control panel	
5	Video editing panel	
6	Washing room	
7	Furniture storage	
8	Recording room	
9	Change clothes partition	
10	Makeup partition	
11	Washing room	
12	Main electrical panel	
13	generator	
14	Kitchen disk storage	
15	Muppets storage	
16	Maneuvering area	For kitchen disk and Muppets
17	Maneuvering area	For Movable décor tableaus
18	Movable décor tableaus storage	
19	Maintenance workshop	
20	Maneuvering area	
21	Spares storage	
22	Maintenance entry	
23	Power entry	
24	Furniture entry	

The 5S implementation in the TV Studio

An audit was conducted in the following areas: TV Studio (Recording Room), movable décor tableau storage, and the furniture room. As a result of the audit, corrective actions were generated and assigned to individuals. A summary of the corrective actions required are listed below.

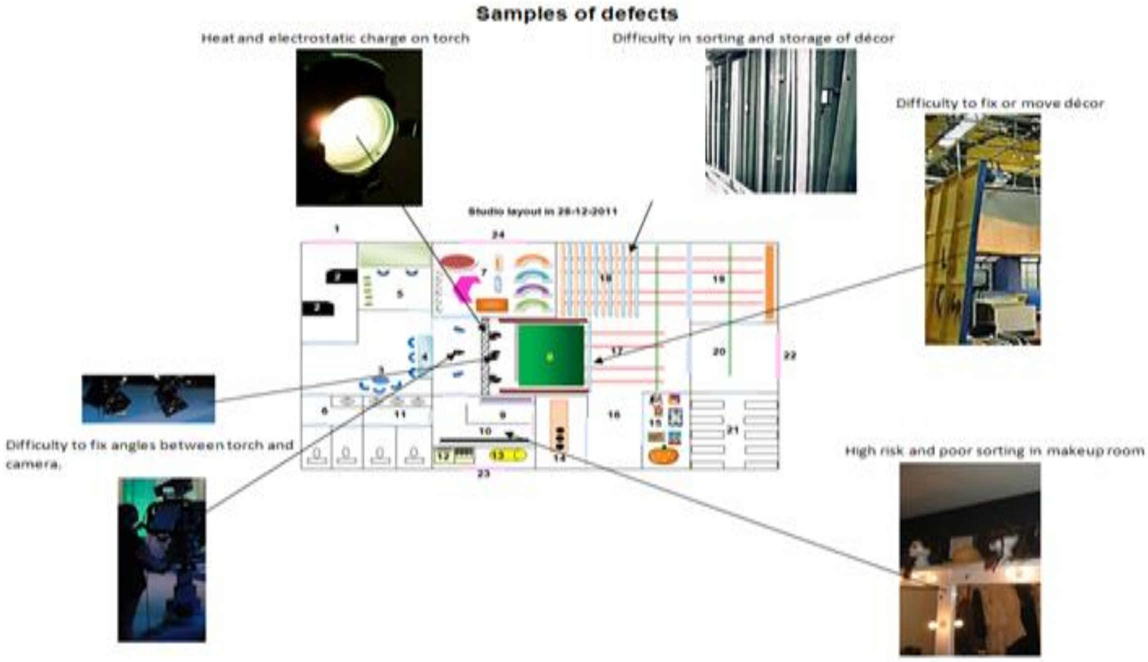


Figure 5-10 Examples of defects in traditional studio

Figure 5-10 provides examples of various defects that occur in a studio space. Each one poses a level of risk, for instance, the heat and the electrostatic charges on the lighting are considered significant risks that should be minimised. There are other defects such as poor storage, and difficulties associated which scenery fixing, etc.

- The 5S results in TV studios:

TV Studio (Recording room) (8) before applying 5S (Figure 5-11):

- Disorganised area (Random arrangement)
- Difficulty to move freely due to wiring

TV Studio (Recording room) (8) after improvement and applying 5S (Figure 5-12):

- Change in studio layout; the wires are packed in lines which makes the area safer
- Easy to move through

Figure 5-11 TV Studio before applying 5S

Figure 5-12 TV Studio after applying 5S

- The 5S results in décor storage:

Décor storage (18) before applying 5S improvements:

- Tableaus not categorised
- Not enough space between tableaus.
- Tableaus outer margins not justified

Décor storage (18) after applying 5S improvements (Figure 5-13):

- Tableaus categorised into five classes according to video recording activity.
- Tableaux timber and Tableaux outlets coloured in different colours for every class and the space between classes is limited to double class occupation thickness on the track.
- Tableaus outer margins are aligned and the storage floor is coloured yellow for the margin limit and green for the handler moving area.

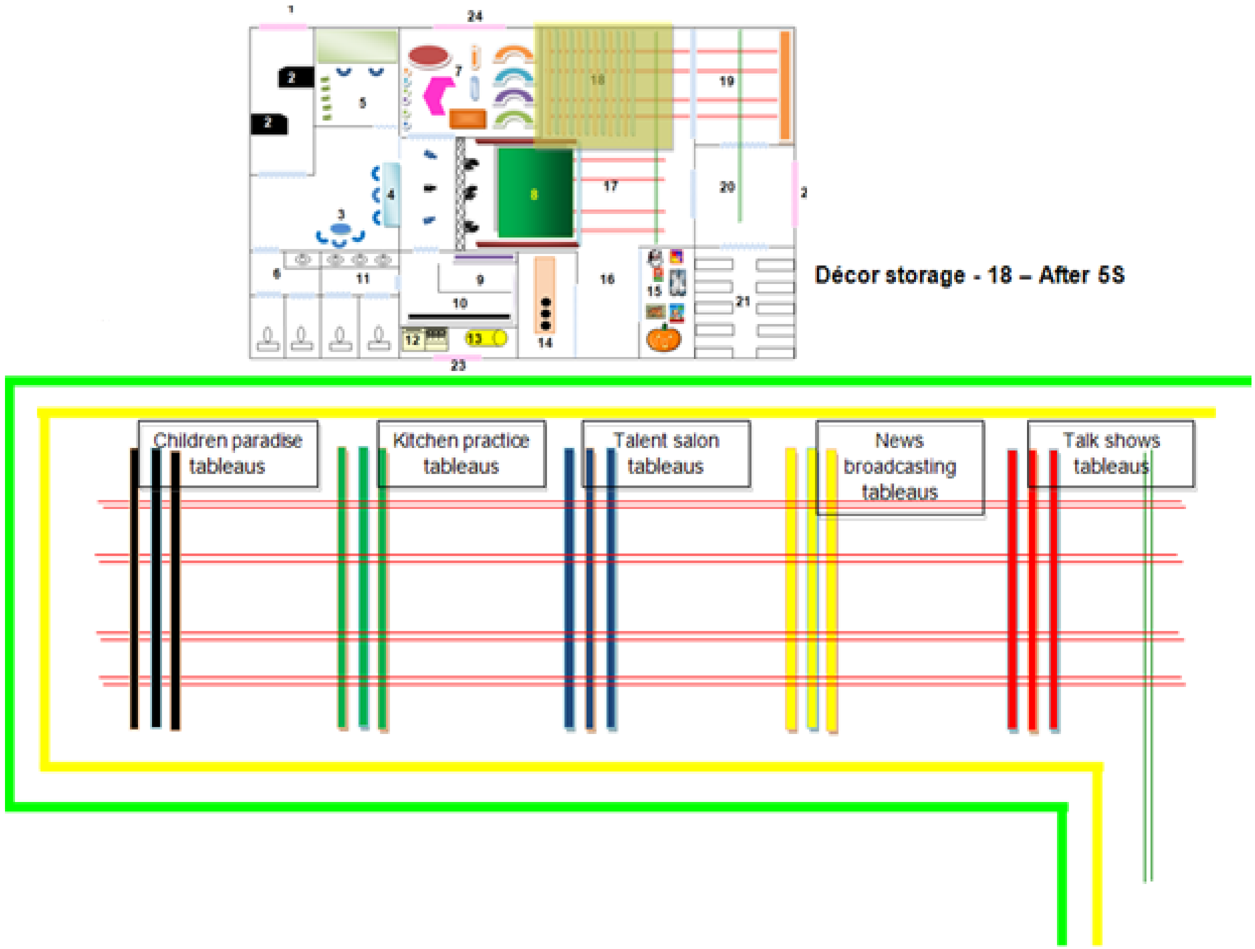


Figure 5-13 Décor storage after applying 5S

(Due to security and organisation policies, photos are not allowed to be taken)

- The 5S results in furniture storage

Furniture storage (7) before applying 5S improvements:

- Random storage.
- Difficult to move through

Furniture storage (7) after applying 5S improvements (Figure 5-14):

- Four parallel storage areas lined in yellow colour
- A chair-width path left free for moving from outdoor gate to indoor gate

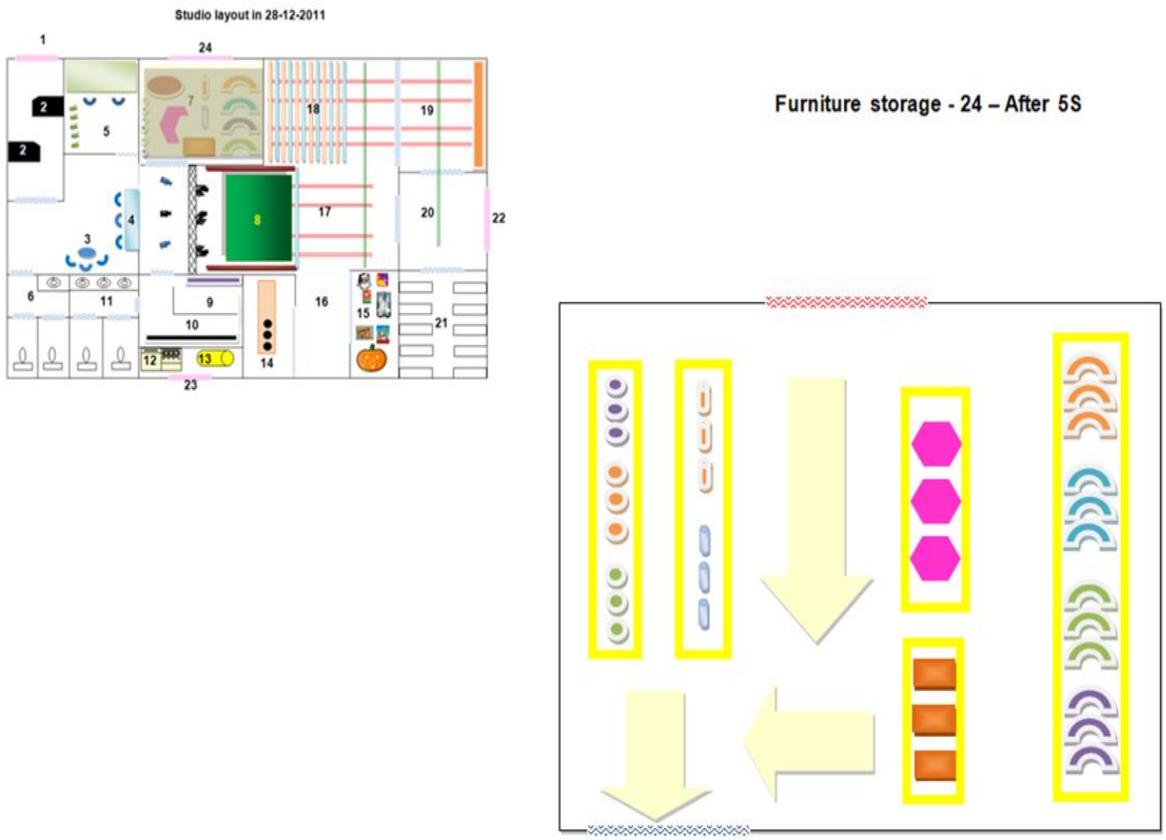


Figure 5-14 Furniture storage after applying 5S

(Due to security and organisation policies, photos are not allowed to be taken)

5.1.2.1.1 5S recorded data and visual control

Visual controls are used for management and employees so that they can easily see the 5S improvement status. Table 5.6 shows the 5S improvements' monthly progress, actual vs target, for each area selected for improvement.

Table 5-6 The 5S Improvement records

Time	Area									
	Spare Storage		Movable décor tableaus storage		Muppets storage		Maintenance Workshop		Furniture Room	
	Actual %	Target %	Actual%	Target %	Actual %	Target %	Actual %	Target %	Actual %	Target %
Dec-11	8	90	11	90	14	90	7	90	12	90
Jan-12	10	90	9	90	15	90	9	90	9	90
Feb-12	11	90	12	90	13	90	10	90	10	90
Mar-12	15	90	17	90	20	90	15	90	22	90
Apr-12	23	90	25	90	30	90	21	90	30	90
May-12	35	90	33	90	39	90	30	90	41	90
Jun-12	53	90	59	90	62	90	48	90	66	90
Jul-12	69	90	66	90	70	90	54	90	78	90
Aug-12	74	90	77	90	78	90	65	90	86	90
Sep-12	80	90	81	90	81	90	75	90	90	90
Oct-12	88	90	85	90	89	90	80	90	90	90
Nov-12	92	90	89	90	94	90	89	90	93	90
Dec-12	94	90	95	90	99	90	91	90	96	90
Jan – 13	**100**	**90**	**100**	**90**	**100**	**90**	**100**	**90**	**100**	**90**

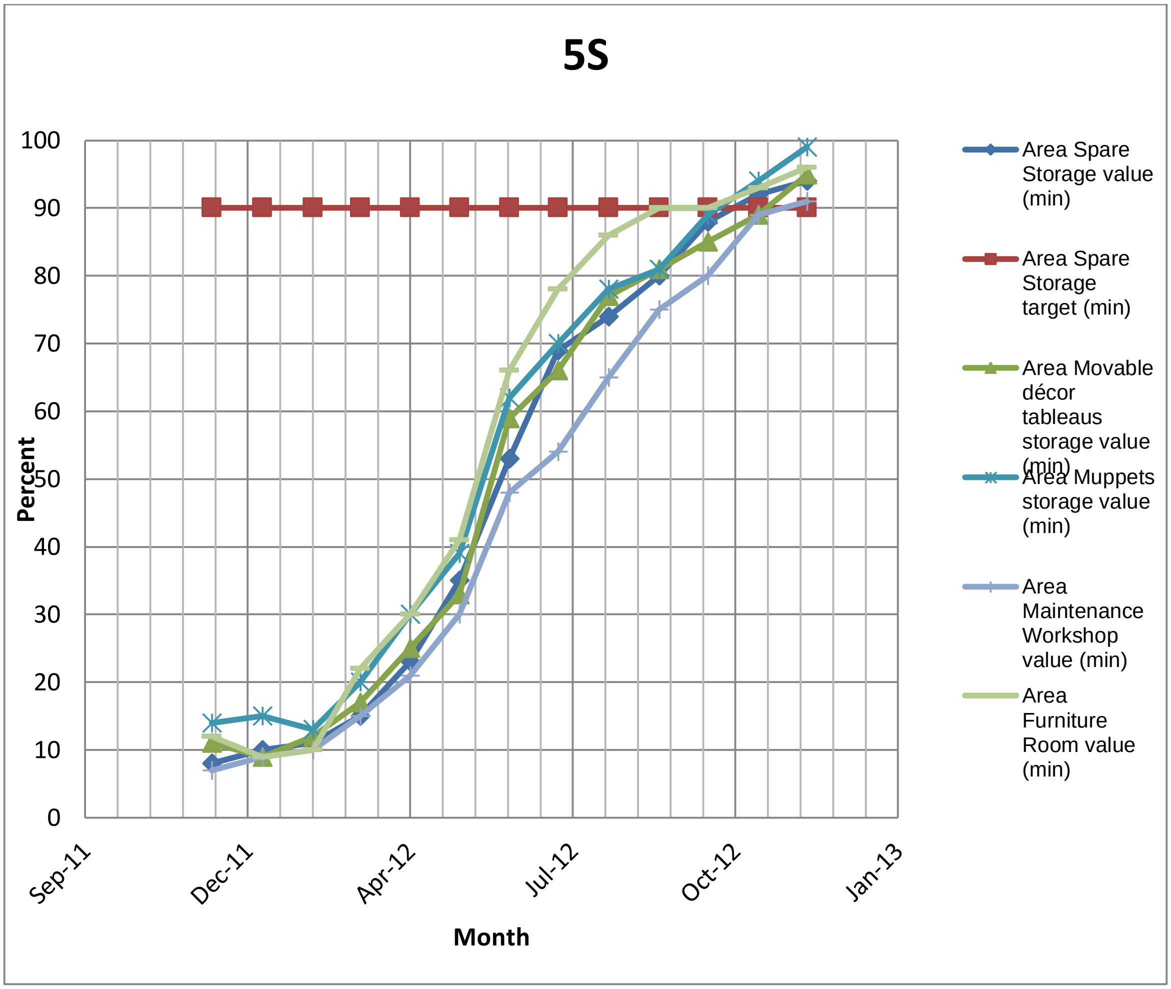


Figure 5-15 The 5S Improvement

Figure 5-15 above illustrates the percentages of 5S monthly improvements from September 2011 to January 2013, where diverse zones are shown in the curve. Furthermore, the table above clearly indicates 5S improvements in the storage areas. The information is presented as a comparison in order to investigate, in-depth, the differences and potentials.

5.1.2.2 Value Stream Map (VSM)

The main purpose of the application of a Value Stream map is to minimise process time. Again, in order to utilise knowledge from previous work, especially 5S and the safety risks of each area, a team was selected to apply VSM. Data and records were obtained using a stop watch. The recording process steps are outlined in Figure 5-16, along with the standard time to complete each step with regard to fall, electric and fire hazards. The objective is to minimise the time required to complete each step; the hazards associated with each step are also minimised, resulting in safety improvement. As a result of the employees' training, the time to complete each step in the process is decreased. Table 5.7 shows the monthly current and target values in minutes for décor preparation, loading and unloading, recording test, and doors. Based on their 5S training, the team achieved a significant improvement. For the décor preparation, the current time started as 17 minutes in December 2011 and ended at 8 minutes in December 2012. For loading and unloading, the current time started at 15 minutes in December 2011 and ended at 5 minutes in December 2012. For the recording test, the current time started at 18 minutes in December 2011 and ended at 3 minutes in December 12. For doors, the current time started at 7 minutes in December 2011 and ended at 3 minutes in December 2012. These results indicate that the employees' training was effective as the time to complete each step improved.

Figures 5-17, 5-18, 5-19 and 5-20 depict the improvement graphs related to decoration preparation, loading and unloading, recording test, entry, manoeuvring and exit. All areas met the improvement target as a result of employee training.

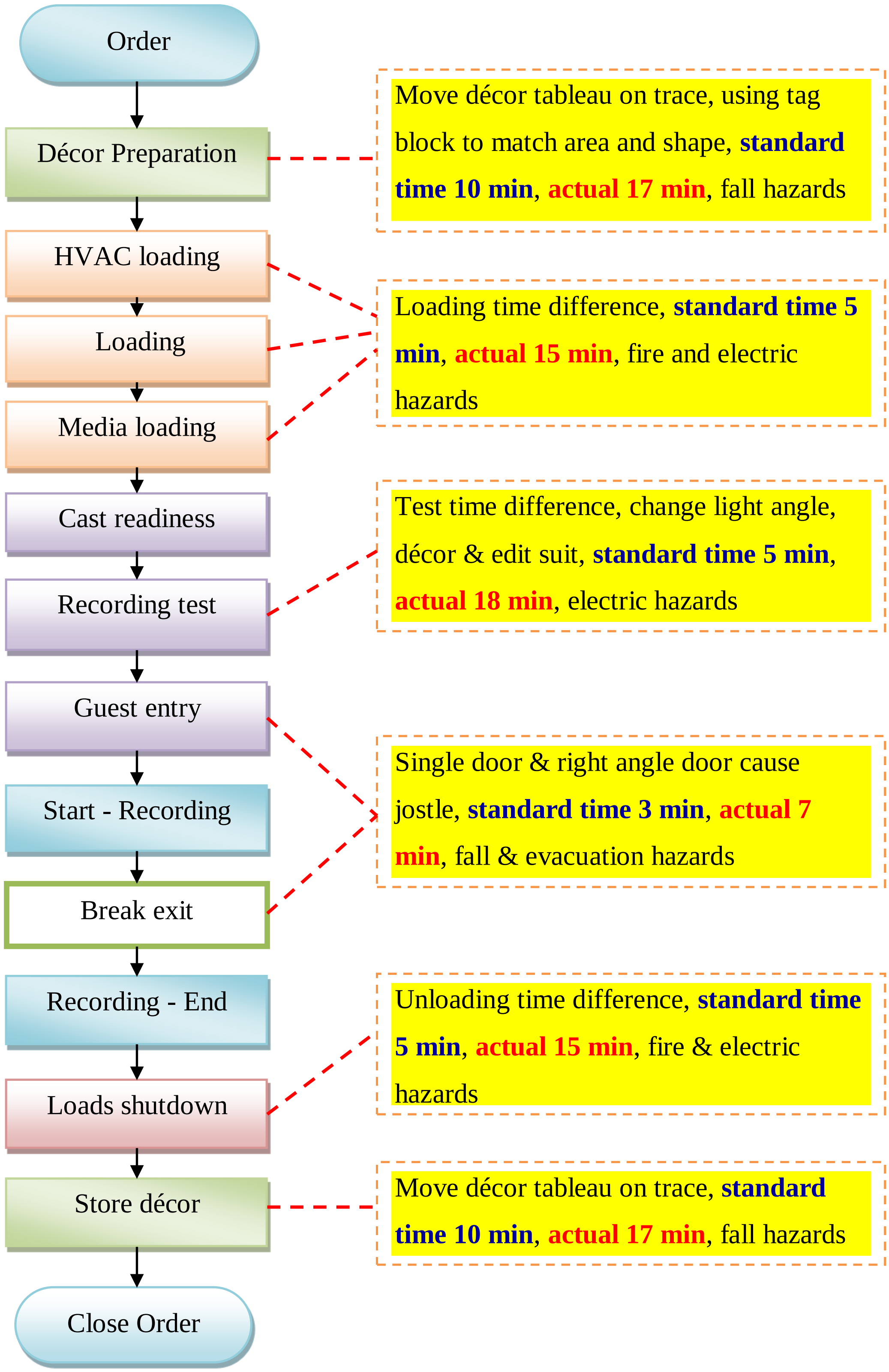


Figure 5-16 The programme order process maps

Table 5-7 Value stream mapping record:

Actual time vs targeted time for the following procceses: décor preparation, loading and unloading, recording test, and doors

Time	Step							
	Décor Preparation		Loading and Unloading		Recording test		Doors	
	Value (Actual) (min)	Target (min)	Value (Actual) (min)	Target (min)	Value (Actual) (min)	Target (min)	Value (Actual) (min)	Target (min)
Dec-11	17	10	15	5	18	5	7	3
Jan-12	17	10	14	5	18	5	8	3
Feb-12	16	10	15	5	17	5	12	3
Mar-12	17	10	13	5	18	5	7	3
Apr-12	14	10	9	5	18	5	5	3
May-12	15	10	9	5	12	5	4	3
Jun-12	12	10	7	5	10	5	4	3
Jul-12	13	10	6	5	10	5	4	3
Aug-12	12	10	6	5	10	5	3	3
Sep-12	10	10	6	5	9	5	3	3
Oct-12	10	10	5	5	7	5	3	3
Nov-12	8	10	4	5	3	5	2	3
Dec-12	8	10	5	5	3	5	3	3

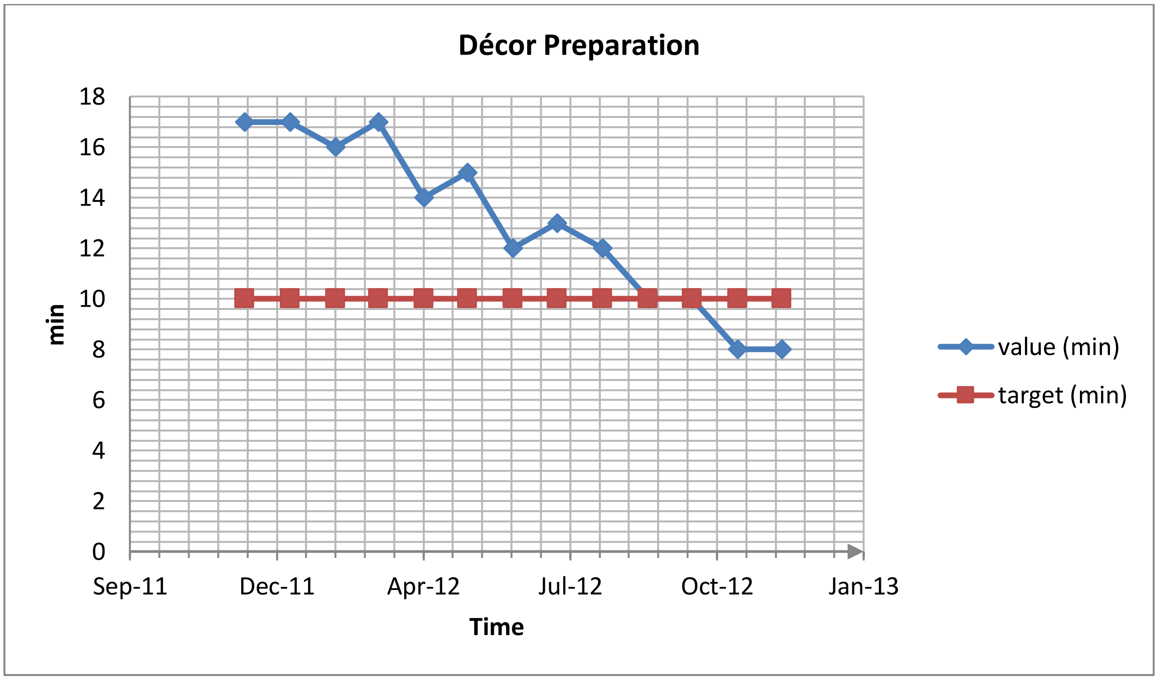


Figure 5-17 Decor preparation time (both target and actual)

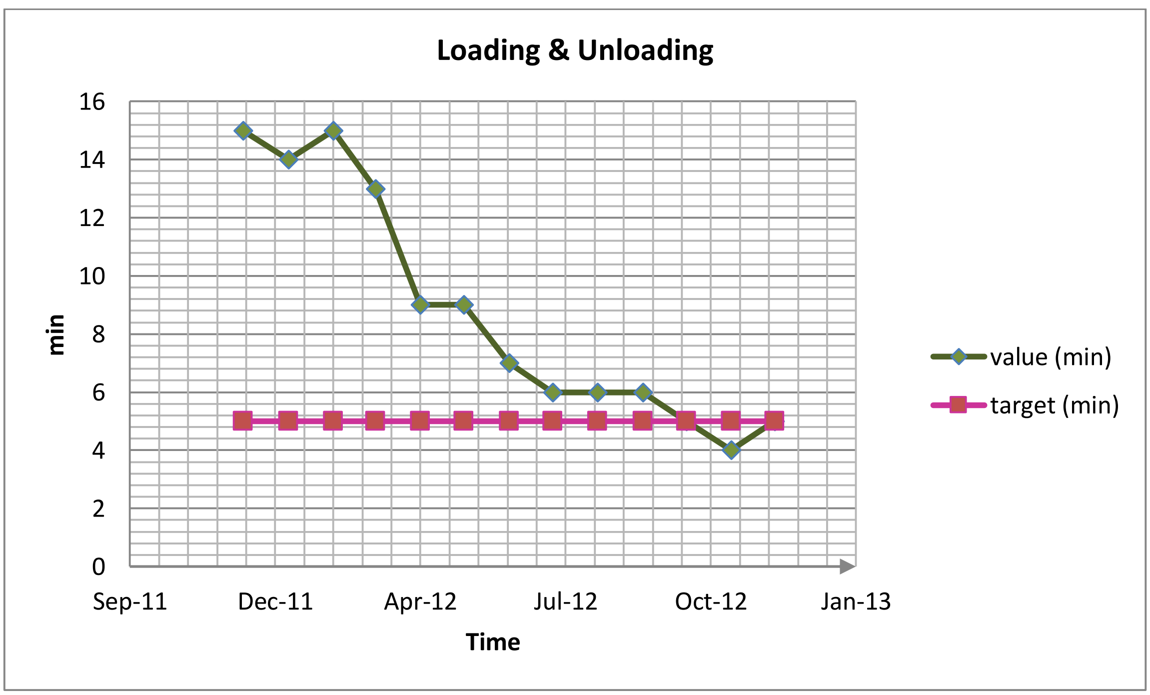


Figure 5-18 Loading time (both target and actual)

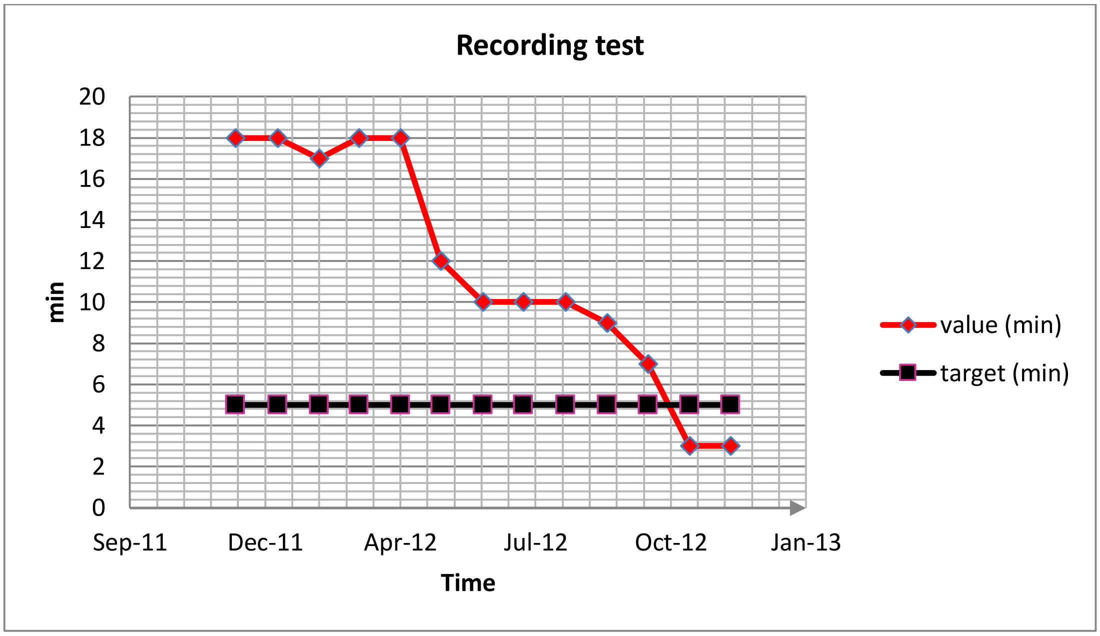


Figure 5-19 Recording test time (both target and actual)

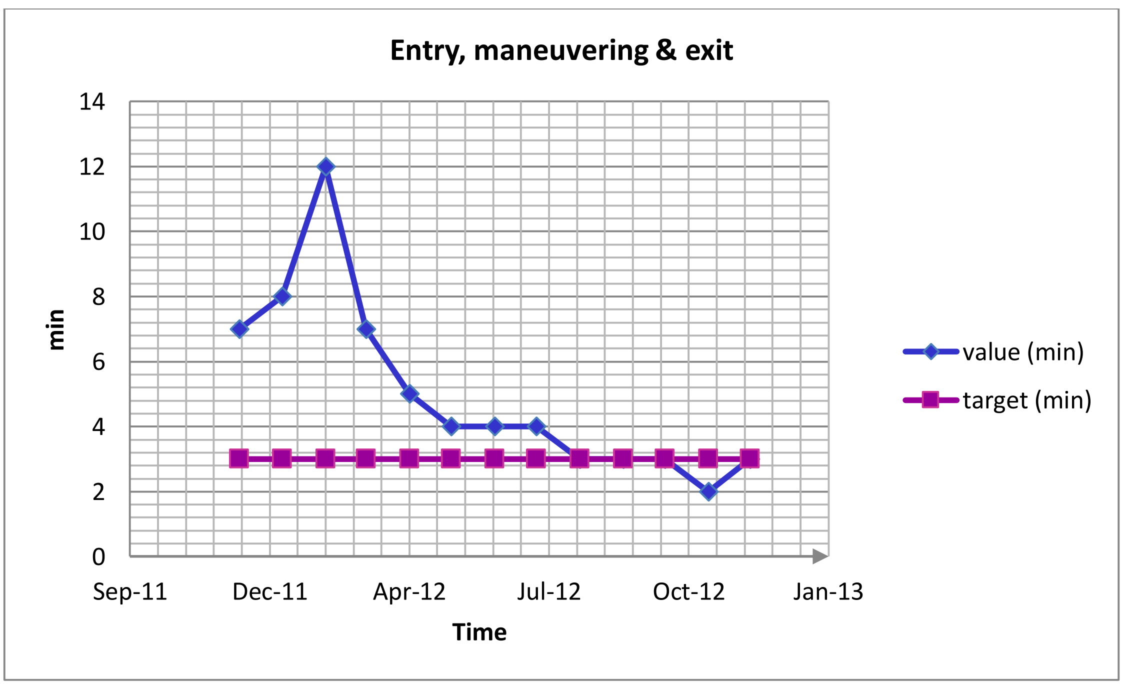


Figure 5-20 Manoeuvring time (both target and actual)

5.1.2.2.1 Value Stream Mapping for Décor preparation

The training and 5S implementation played a major role in reducing the time in décor preparation and made the TV studio more organised. The current state of the décor preparation process steps had to be first mapped. Figure 5-21 is the Value Stream map for the current state; it outlines each step in the process and the time required to complete each step. Also, it indicates the value-added time (17 minutes) and non-value-added time (6 minutes). The VSM shows the steps that consume more time and can therefore be targeted for improvement. Figure 5-22 shows the future state after the improvements had been implemented. It shows the value-added time reduced to 8 minutes and non-value-added time reduced to 40 seconds, indicating that the corrective actions and improvements were effective. It was clear that the organised area and training were very important factors in the reduction of the total time and in making the process of décor preparation more efficient.

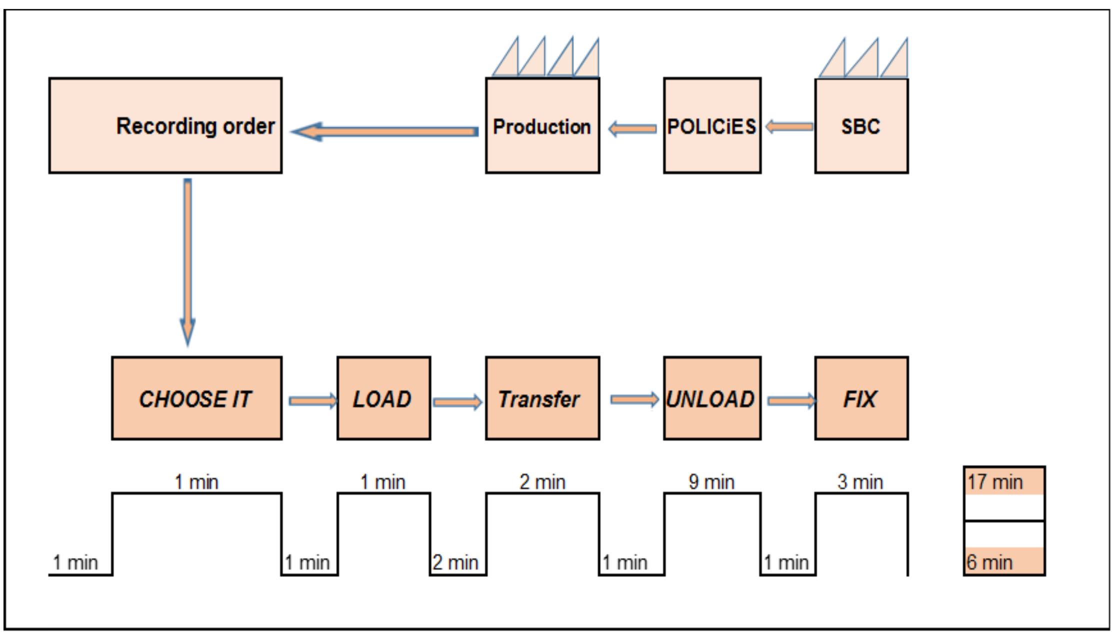


Figure 5-21 VSM , Worst Case Scenario

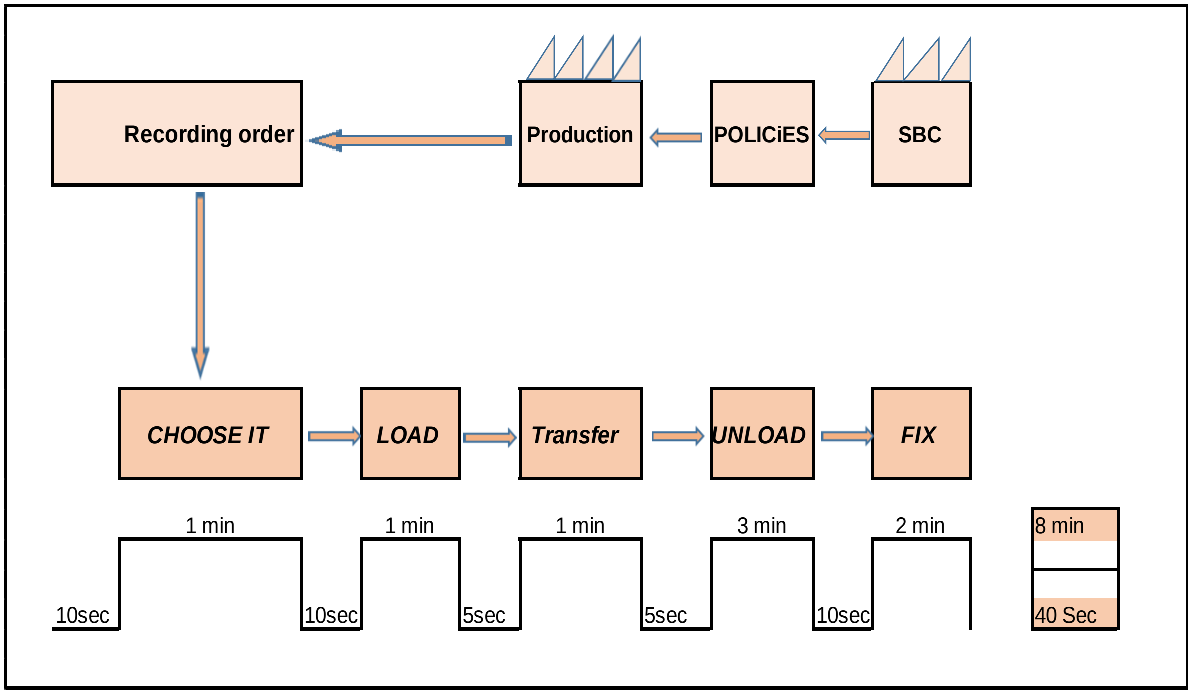


Figure 5-22 VSM, Best Case Scenario

5.1.2.3 Poka-Yoke

Poka-Yoke is used to minimise mistakes by operators; its main objective is to eliminate or minimise defects by preventing and correcting human errors as they occur. As in the previous sections, all knowledge continues to develop and is applied in this section. Most manual work by workers is subject to mistakes and the application of Poka-Yoke minimises these mistakes, as illustrated in the following sections.

5.1.2.3.1 Before applying Poka-Yoke

A. Illumination system in the traditional studio

- The three main types of lighting (key, fill, and back) were manually angled as depicted in Figure 5-23. Lighting may be increased or decreased without taking into consideration the temperature or the effect on electrical cables; these unsafe conditions with unsafe actions lead to fall, electric, fire and burn hazards. In addition, it takes extra time to achieve the best lighting positions.

Figure 5-23 Manual adjustment for lighting

B. Décor in the traditional studio (Figure 5-23)

Below are highlighted some of the causes for fall, electric, and fire hazards in the décor area:

- Wooden painted tableaus were pre-prepared for every class of programmes (Children, Kitchen, Talent, News, and Talk Show recordings). This makes it more dangerous and likely to cause a fall accident.

- These wooden tableaus were moved from the storage place to the back of the recording (video capturing area) platform. This is dangerous as they may fall; besides there is a high probability of causing fire or electric hazards because of their incorrect electrical connections and plugging.
- The two sides of each tableau are covered with wooden blank tableaus covered by a flexible scene for every recording, as the programme director orders.
- These flexible scenes were fixed by tag blocks on the highest edge of each side of the wooden blank tableau. Again, this makes it more dangerous in terms of causing fall, fire and electric hazards because of their additions of silk cloth and shadow lights.
- The overall decoration system had a high probability to cause hazards as explained and it took a long time to move the tableaus backwards and forwards in order to transfer them from and to the storage places.

Figure 5-24 Traditional TV studio

5.1.2.3.2 After applying Poka-Yoke

A. Improvements in the illumination system in the pilot studio (Figure 5-24)

- The main lights were split into two groups:

- (Key, Fill) changed to high frequency electronic lights and installed on a fixed curved metal bar.
- The two electronic lightings were fixed to a movable axis on a step motor in order to take the action signal from the main control panel through green coloured.
- All components in the cooling tunnel, which faced the recording room, to be built in high transparent glass with special specifications such as thermal isolation and low refraction index.
- The third component of the three main lights (back) was replaced by reflectors, installed and fixed on the back left of the Chroma platform, where the captured objects would be.
- The reflectors split into two parts in a triangle shape; the third side of this triangle is parallel to the glass side of the illumination tunnel.

- The setup allowed for automatic readjustment to the maximum pre-programmed value by moving the step motor, taking into consideration the fact that all actions are monitored at the main control desk.

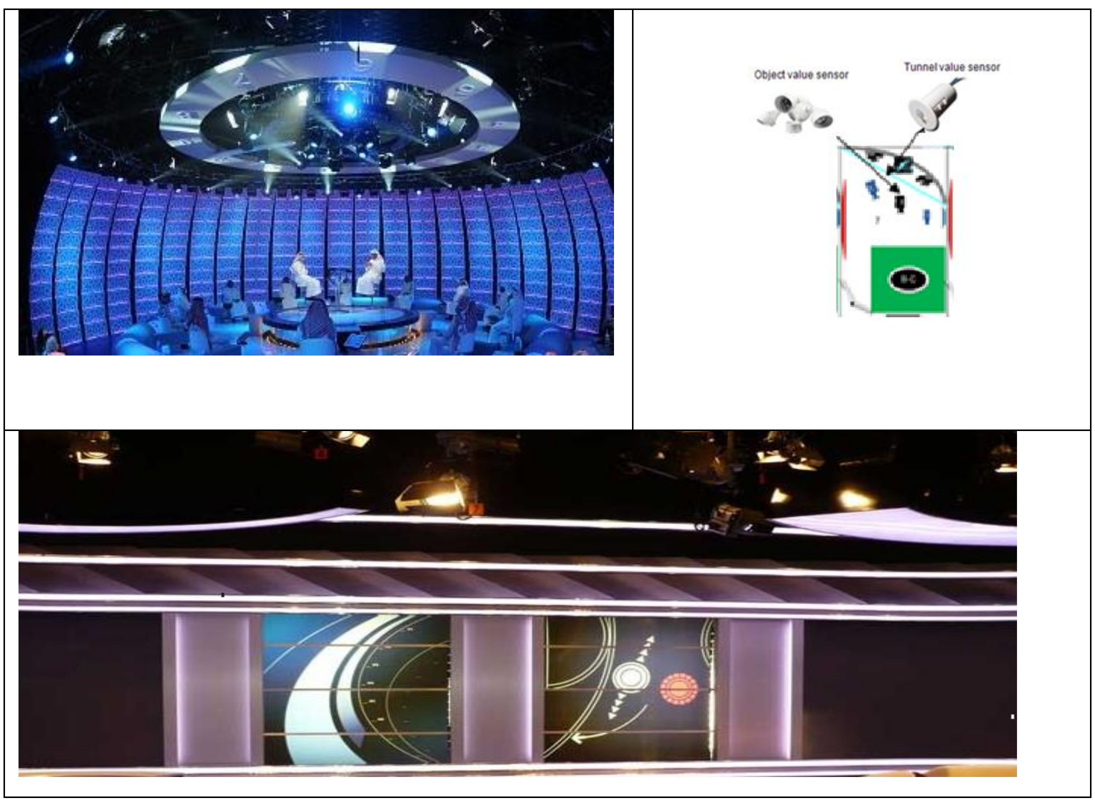
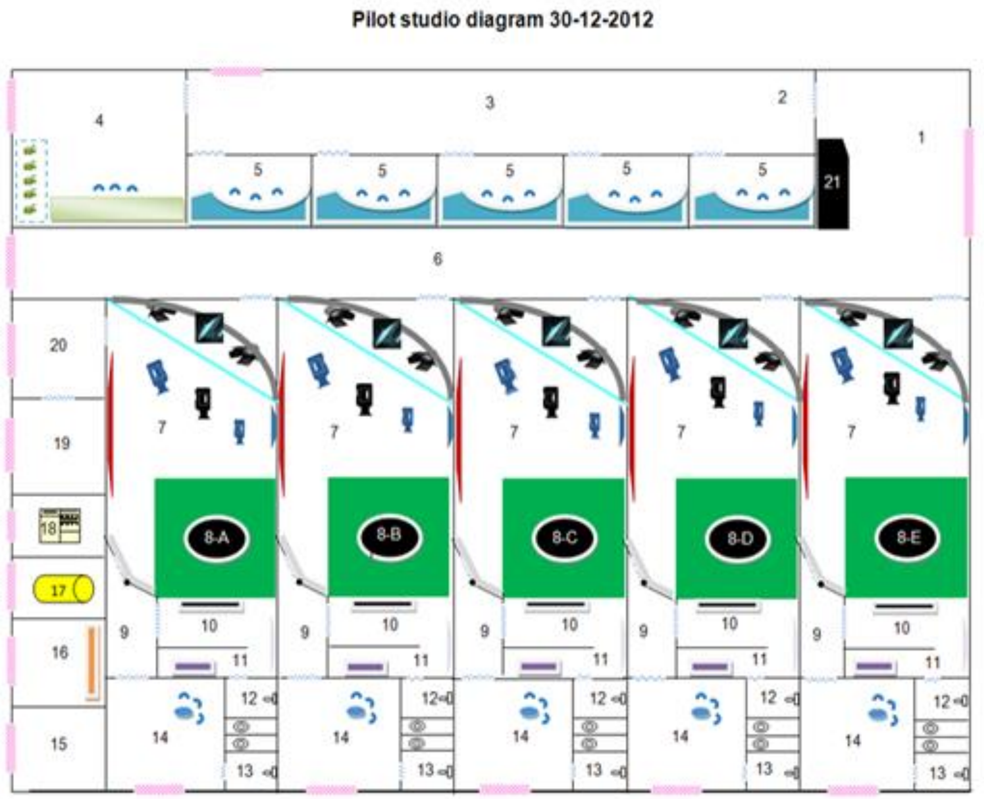


Figure 5-25 Automotive lighting

B. Improvements to the décor in the pilot studio

- Several traditional decoration systems were changed and were replaced by new decoration systems, as presented in Figures 5-26 and 5-27 where:
  - Five recording units were established in five separate platforms and isolated from other sounds and lights, ready to be used in parallel at the same time.
  - A complete Chroma frame was established on the floor, back and right side of every platform, supported by a binuclear Chroma scope installed in the cooling tunnel in the middle of the Key and Fill lights. This Chroma scope enables the programme director to create and use any animations or graphics which he sees as suitable for the programme's subject.
  - Chroma views are focused automatically and configured with the dropped lights through the illumination sensors matrix and the microcontroller panel which are explained in the illumination system.
  - Two side LED screens; a small one on the far right-hand side and a large one on the near left-hand side; these facilitate any additional animations needed by the programme's director to be included in the programme's video scene.



Layout Keys

Key	Element
	External entry
	Internal entry
	Seat
	Reception table
	Washing sink
	WC
	Control disk
	Video editing disk
	Portable edit suit
	Central camera
	Side camera
	Key & fill torches suspension beam
	Key or fill torch
	Chroma platform
	Main LED décor tableau
	Recording direction LED
	Backlight reflector
	Chroma scope
	Workshop cabinet
	Clothes cupboard
	Overall wall mirror
	Makeup disk
	Main electrical panel
	Generator
	Thermal isolated glass

Figure 5-26 Pilot modern studios diagram

Figure 5-27 Current new digital studios

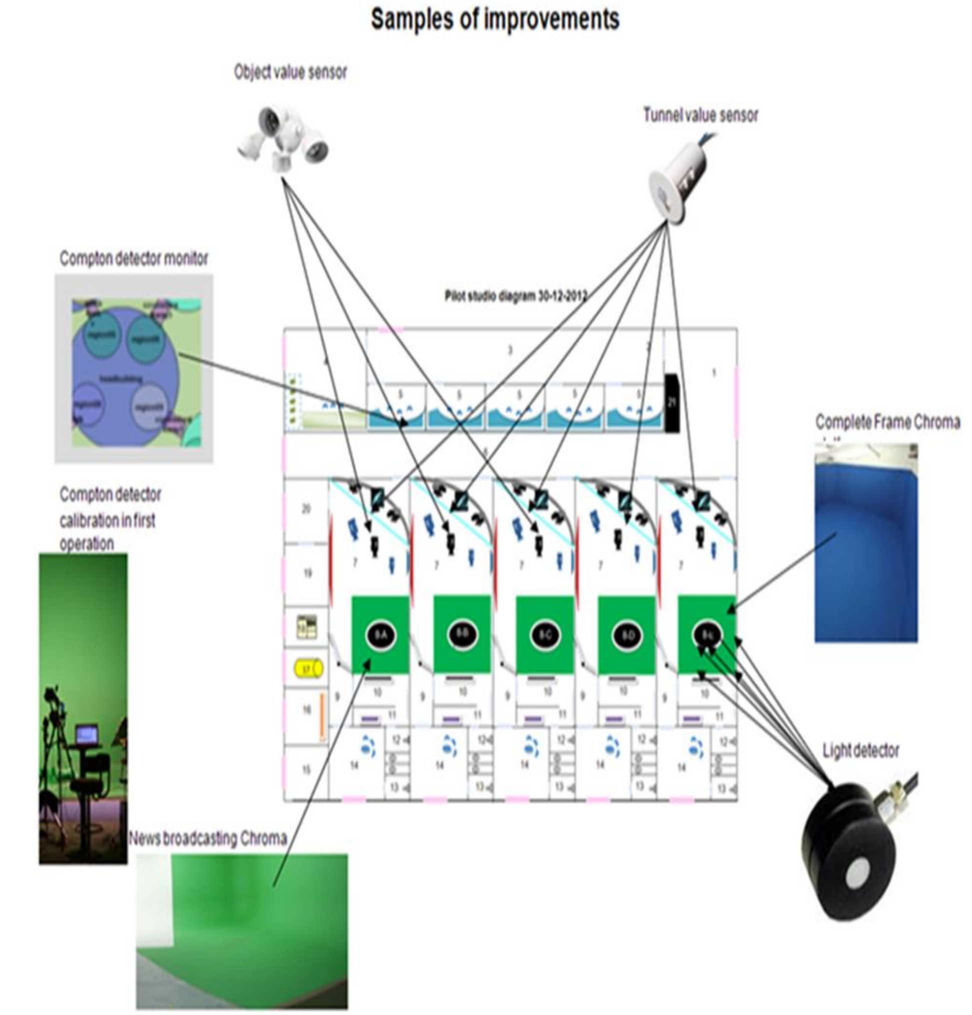


Figure 5-28 Poka-Yoke improvement

5.2 DMAIC Control Phase

The objective of the control phase is to sustain the improvements achieved in the improve phase. The control chart is the most appropriate tool to achieve this objective. The results in the previous section showed improvement by reducing the number of accidents. Table 5-8 depicts the number of accidents caused by electrical hazards; this improved from 25 accidents to 4 accidents per year. The number of accidents caused by fire improved from 15 accidents to 1 accident per year, and the number of accidents caused by fall hazards improved from 36 accidents to 2 accidents per year.

Table 5-8 Accident recording before LSS and after LSS application

TIME	Electrical Hazards			Fire Hazards			Fall Hazards		
	Accident number			**Accident number**			**Accident number**		
	Before LSS 2011/12	**After LSS 2012/13**	**Year 2014**	**Before LSS 2011/12**	**After LSS 2012/13**	**Year 2014**	**Before LSS 2011/12**	**After LSS 2012/13**	**Year 2014**
DEC	1	1	0	3	0	0	4	1	0
JAN	5	0	0	1	0	0	5	0	0
FEB	2	0	0	0	0	0	3	0	0
MAR	1	0	0	1	0	0	4	0	0
APR	3	0	0	2	0	0	3	0	0
MAY	0	2	0	1	1	0	3	0	0
JUN	1	1	0	0	0	0	3	0	0
JUL	2	0	0	2	0	0	2	0	0
AUG	1	0	0	1	0	0	3	1	0
SEP	4	0	0	2	0	0	4	0	0
OCT	2	0	0	2	0	0	2	0	0
NOV	3	0	0	0	0	0	5	0	0
TOTAL	**25**	**4**	**0**	**15**	**1**	**0**	**36**	**2**	**0**

The application of the Lean Six Sigma DMAIC problem-solving model resulted in an significant improvement in safety.

5.2.1 Improvement impact on Failure Mode and Effect Analysis (FMEA)

RPN results have a direct impact on the FMEA studies for electrical, fire and fall hazards. Table 5.11 shows how the improvement achieved reduced the RPN number for all hazards, indicating that the improvements were effective.

Table 5-9 FMEA after applying LSS

Hazard	Process	Potential Failure Mode	Potential Failure Causes	Potential Failure Effects	Action Taken	LSS Tools	After LSS			
							Severity	Occurrence	Detection	RPN
Electric	Lighting adjustment	Wrong angles	Lack of experience	Fuzzy pictures (un clear)	Appropriate Training. Applying Poka-Yoke	Value Stream Mapping, 5S, and Poka-Yoke	4	2	2	16
	Décor preparation	Bad Connection	Inadequate training	Electrical shock	Appropriate training and applying VSM, 5S and Poka-Yoke		4	3	2	24
	Electrical connections	Overheating	Using Bad connectors	Equipment damage	Regular inspection, monitoring, and appropriate training		4	2	4	32
	Recording	Overload	Inadequate training	Equipment damage	Appropriate training		4	3	3	36
Fire	Recording	Overheating	Inadequate insulation	Ignite Fire	Regular safety inspection		4	3	4	48
	Lighting adjusting	Heating up to flammable limit	Bad connectors	Ignite fire	Regular safety inspection and training		4	3	3	36
	Safety inspection	Alarm failure	Bad maintenance	Does not provide fire detection	Appropriate tand proper		4	2	4	32

Hazard	Process	Potential Failure Mode	Potential Failure Causes	Potential Failure Effects	Action Taken	LSS Tools	After LSS			
							Severity	Occurrence	Detection	RPN
					maintenance programme					
Fall	Work organisation	Falling Equipment	Disorganised area	Destroy decoration objects	5S	Value Stream Mapping, 5S, and Poka-Yoke	4	2	4	32
	Lifting equipment	Workers Fall	Inadequate training, and lack of experience	Fatal injuries	Provide intensive safety training		4	3	2	24
	Decoration Preparation	Falling walls	Wall not assembled properly (Décor problems)	Equipment damages	Provide intensive training		4	2	2	16

The Highest RPN for the electrical hazards reduced from 392 to 36, for fire hazards from 392 to 48, and the RPN for the fall hazards reduced from 343 to 32.

5.2.2 Assessment After Implementing LSS and HSMS

After the implementation of the proposed LSS and HSMS in the media industry, it can be seen that this implementation has reduced the probability of occurrences of the majority of the causes.

5.2.2.1 Electrical Hazards Assessment

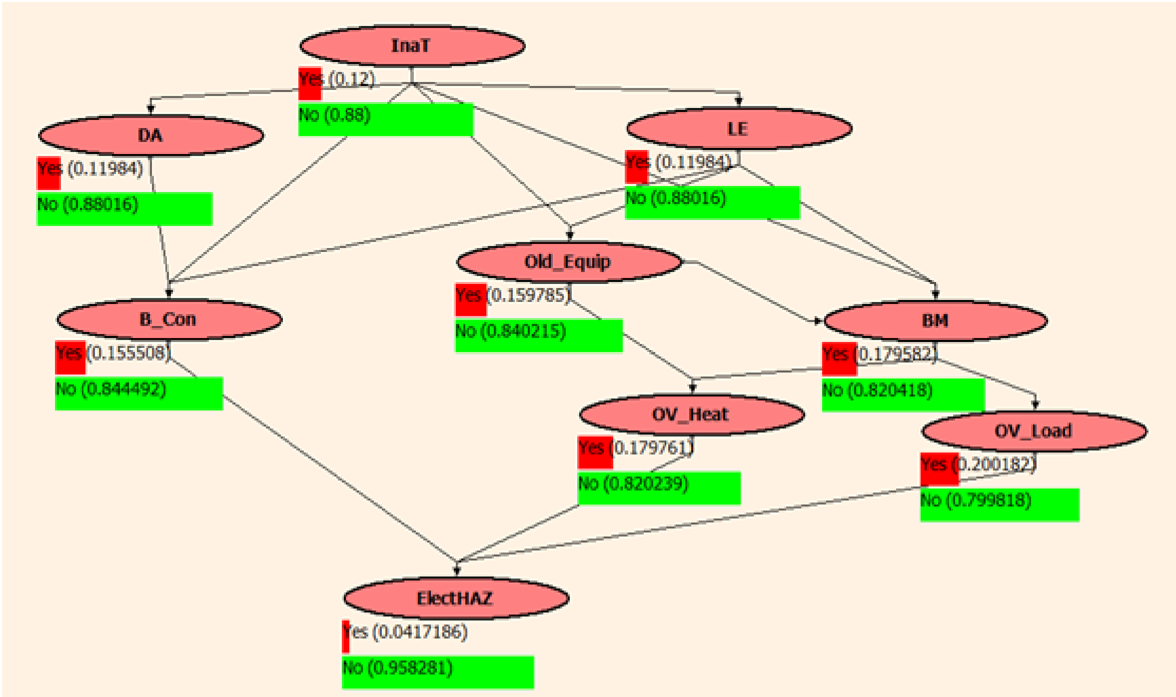


Figure 5-29 A BBN network assessment for electrical hazards after LSS improvement

After improvement, the probability of occurrence of the main and sub causes of electrical hazards became low for most of the causes. Also, there was a remarkable decrease in the probability of occurrence in most of these causes. For example, the probability of the occurrence of inadequate training is 12%, the probability of lack of experience is 11.98%, and the probability of a disorganised area is 11.98%. The overall probability of electrical hazards occurring after the improvement reduced to 4.2%, which means that there is a reduction in the probability of electrical-related hazards by 68.4% as a result of the improvement.

5.2.2.2 Fire Hazards Assessment

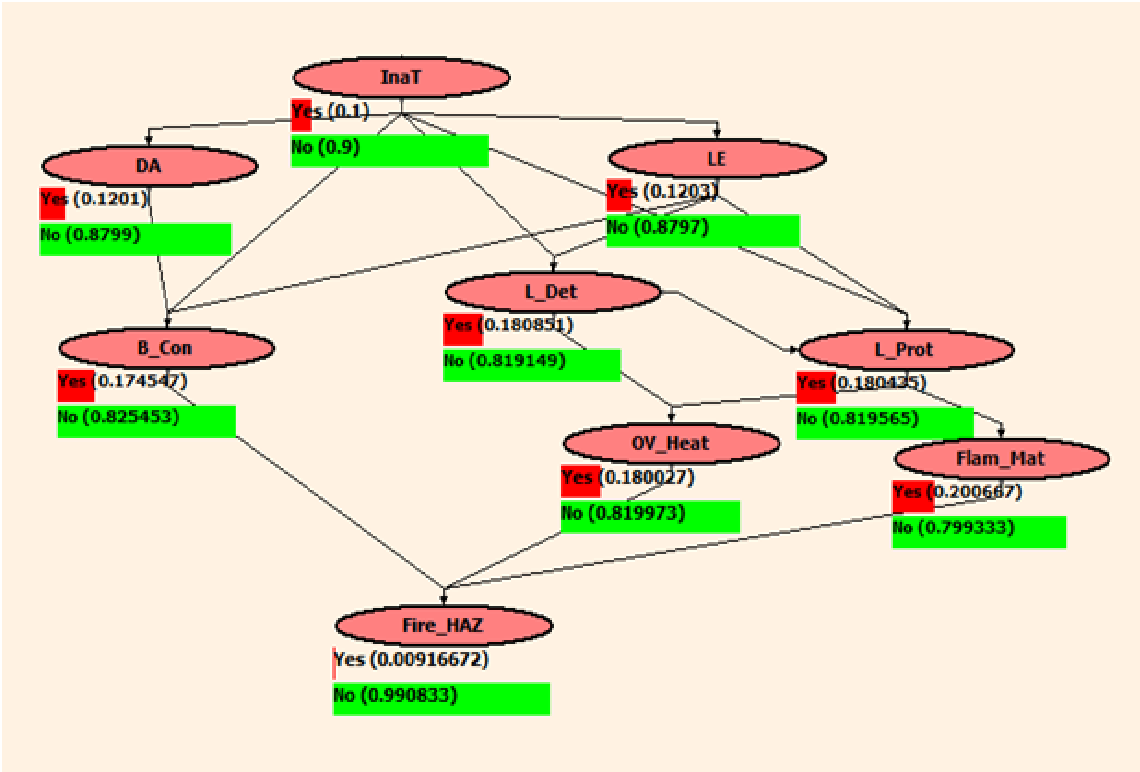


Figure 5-30 A BBN network assessment for fire hazards after LSS improvement

After improvement, the probability of occurrence of the main and sub causes of fire hazards became low for most of the causes. Also, there was a remarkable decrease in the probability of occurrence in most of these causes. For example, the probability of the occurrence of inadequate training is 10%, the probability of lack of experience is 12.03%, and the probability of occurrence of a disorganised area is also 12.01%. The overall probability of fire hazard occurrences after the improvement reduced to 0.9%, which means that there is a reduction in the probability of fire-related hazards by 84.2% as a result of the improvement.

5.2.2.3 Fall Hazards Assessment

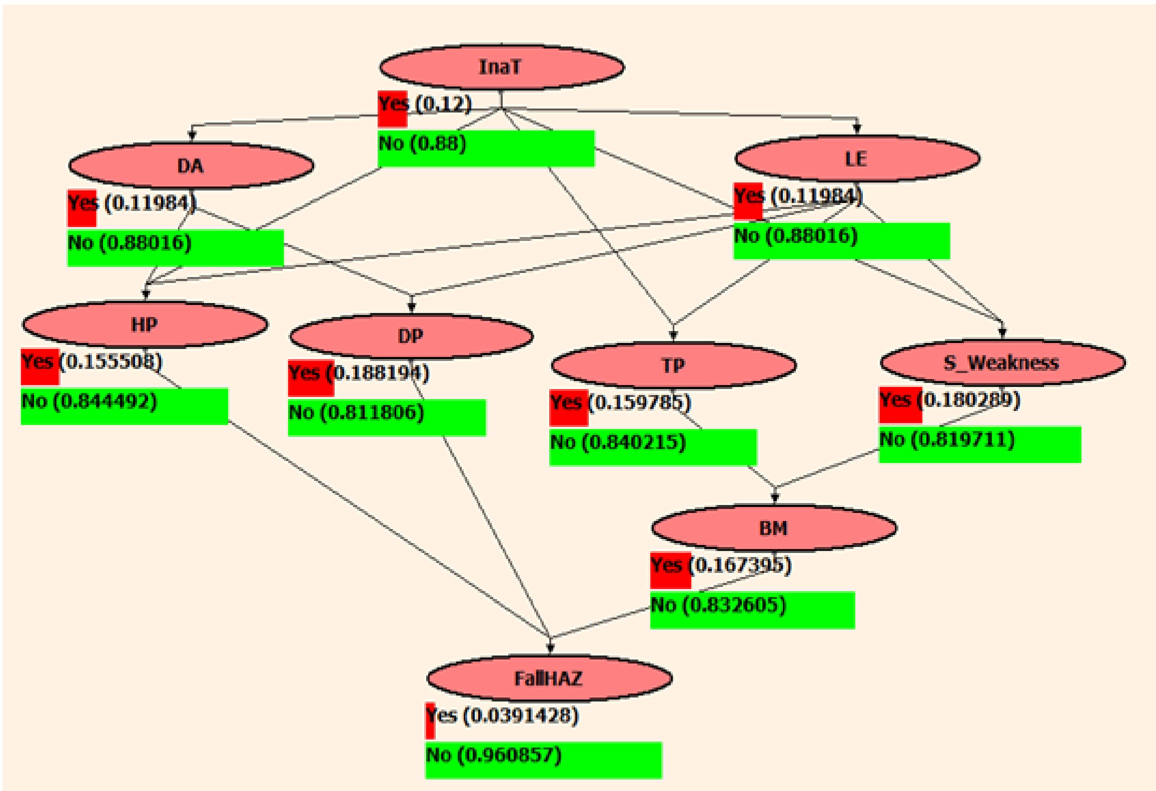


Figure 5-31 A BBN network assessment for fall hazards after LSS improvement

After improvement, the probability of occurrence of the main and sub causes of fall hazards became low for most of the causes. Also, there was a remarkable decrease in the probability of occurrences in most of these causes. For example, the probability of the occurrence of inadequate training is 12%, the probability of lack of experience is 11.98%, and the probability of a disorganised area is 11.98%. The overall probability of fall hazard occurrences after the improvement reduced to 3.9%, which means that there is a reduction in the probability of fall-related hazards by 80.2% as a result of the improvement.

5.2.3 SPC Control Chart: C-Chart

The purpose of the control phase is to sustain the improvement established in the previous phase. The Control Chart (c-chart) method is best suited to this objective. The c-chart was an ideal tool for validating the improvement achieved as a result of Lean Six Sigma implementation and for monitoring the process for any out-of-control condition. Any out-of-control condition initiates a corrective action to eliminate any special causes of variation which in this case result in hazards. Special causes refer to factors that cause the process to be unstable and unpredictable over time.

The c-chart is a type of control chart used to monitor the total number of events occurring in a given unit of time. In this study, the events are the number of accidents occurring per month. The c-chart was applied to monitor count data which is assumed to have come from a Poisson distribution with parameter µ - this value is both the mean and the variance. µ is the average number of accidents and is estimated from the data. The number of accidents occurring is plotted against time. µ is also the centre line on the c-chart and it is used to calculate the control limits.

The control limits for the c-chart are $\bar{c} \pm 3\sqrt{\bar{c}}$ where, $\bar{c}$ is the estimate of the long-term process mean.

The following is a sample calculation for c-chart control limits for electrical hazards before implementing Lean Six Sigma:

$\bar{c}$ = 2.083 It is the centre line on the chart

$\sqrt{\bar{c}}$ = 1.443

$3*\sqrt{\bar{c}}$ = 4.329

UCL = 2.083+4.329 = 6.413

LCL = 0

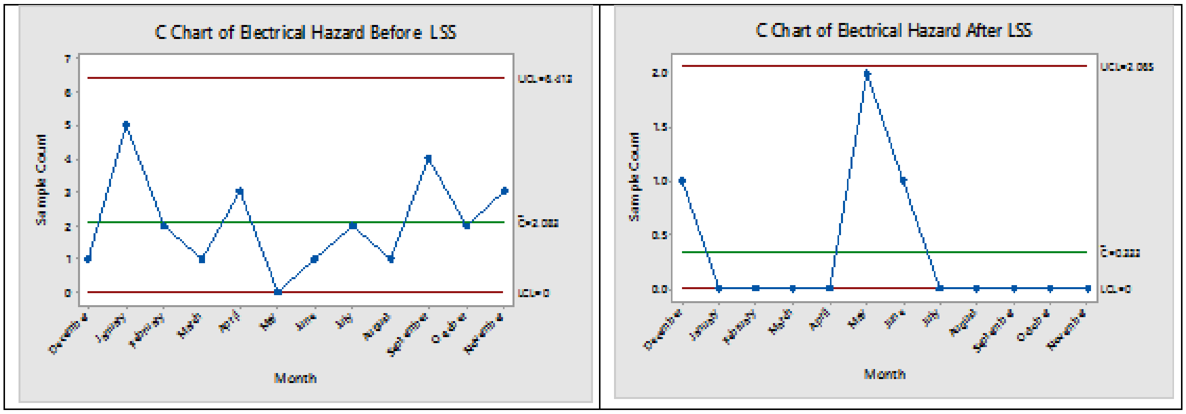


Figure 5-32 C-Charts for electrical hazard before and after LSS improvement

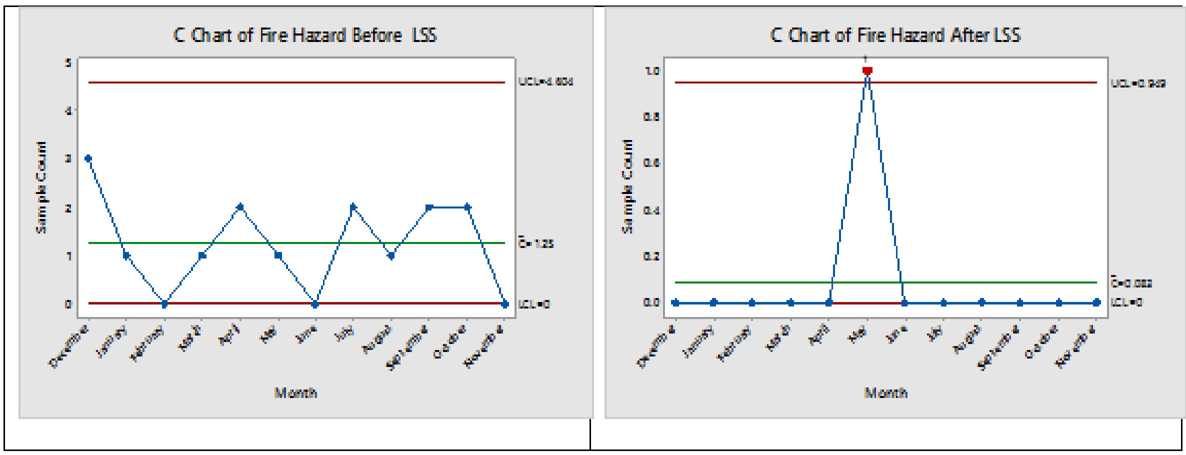


Figure 5-33 C-Charts for fire hazards before and after LSS improvement

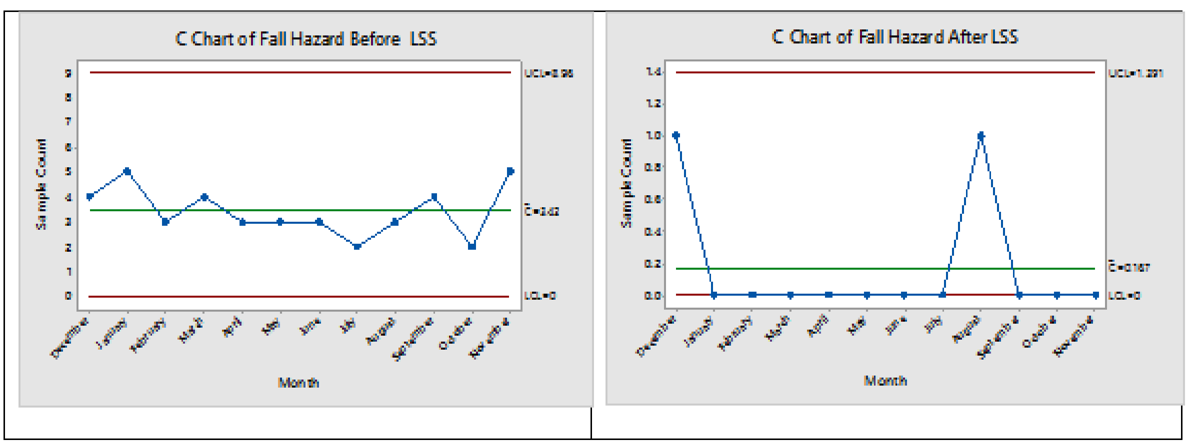


Figure 5-34 C-Charts for fall hazards before and after LSS improvement

The c-charts in Figures 5-32, 5-33, and 5-34 show significant improvements in all hazards. The $\bar{c}$ for electrical hazards decreased from 2.083 to 0.333, the $\bar{c}$ for fire hazards decreased from 1.250 to 0.0833, and the $\bar{c}$ for fall hazards decreased from 3.417 to 0.167. The out-of-control signal noted on the c-chart for fire hazards after implementing Lean Six Sigma, depicted in Figure 5-33, was the result of a new employee that had not gone through safety training. Overall, intensive training improved employee skills and experience significantly and that led to zero accidents in 2014. It was found that employee safety training was the most significant factor in the improvement. The study showed that the application of the Lean Six Sigma problem-solving method to be effective in a setting such as the Saudi Broadcasting Corporation.

In summary, this chapter covers the improvement phase. The Taguchi experiment was conducted to investigate the effects of training, experience, age, and qualification of the employees, and the response time to the alarm on extinguishing time and percentage of damage. Training, experience and response to alarm variables are found to be significant factors for both extinguishing time and percentage of damage.

5S implementation in the studio minimised the fire, electric, and fall hazards, and improved overall safety. The Value Stream map improved cycle time for décor preparation, loading and unloading, recording, and doors. Poka-Yoke minimised defect occurrences by reducing manual work to prevent and correct human errors. Failure Mode and Effect Analysis was effective in validating improvements, and finally Statistical Process Control, the c-chart, was also effective in sustaining and confirming the improvements.

CHAPTER 6: CONCLUSION:

6.1 Introduction

Lean Six Sigma philosophy and tools have been applied successfully in many organisations and government agencies. However, the literature does not provide a framework for implementing Lean Six Sigma in TV studios. This research shows the successful implementation and application of Lean Six Sigma tools and principles in a transaction-based environment such as a TV studio. It integrates Lean Six Sigma and occupational health and safety management systems, including FBD, FMEA, Pareto principles, and BBN to identify, eliminate and minimise safety hazards. The Taguchi method was applied to identify the significant factors that affect electric, fire and fall hazards in order to eliminate or minimise their effects to improve safety, 5S was implemented to improve safety, the Value Stream Map (VSM) was utilised to improve process efficiency, Poka-Yoke was applied to remove and eliminate human errors, and the control chart was employed to validate and sustain improvement.

6.2 Integration of LSS and OHSMS

Occupational Health and Safety Management Systems (OSHMS) is an integral part of any organisation, including the media industry since it is not immune to dangerous hazards. Electric, fire and fall are among these hazards. It is important for OSH systems to improve employees' performance and safety and decrease the costs associated with these hazards.

This research has showed by that integrating Lean Six Sigma process improvement tools and Occupational Health and safety Management Systems (OSHMS), a significant reduction in electric, fire and fall hazards can be achieved. The Lean Six Sigma DMAIC application has been used to mitigate these risks, and to implement behaviour-based safety in the workplace, it is a proactive approach to addressing safety issues and promoting and achieving a safety culture in any organisation. Some of the results of the improvements include cost reductions, improved safety and quality, and increased productivity.

6.3 Zero-accident culture

Another positive consequence of this research is the recognition of the fact that work- related accidents are avoidable and preventable, and as a result, policies and procedures were established to support a zero-accident culture in the workplace. The zero-accident culture programme was vital and led to minimising accidents and improving employees' moral.

6.4 The Challenge of Combining of C&E Analysis, FMEA, Pareto Principles, and BBN

Whilst it is straightforward to combine cause-and-effect analysis, FMEA and the Pareto principle, their further integration with Lean Six Sigma and BBN poses some challenges. Firstly, although LSS has been increasingly used, the theoretical framework has not yet been developed and is generally lacking. The use of various tools in LSS varies from application to application. Secondly, since BBN models the detailed relationships and probability interdependences between various variables, it requires separate software to implement and evaluate the results. Thirdly, the data sources used for FMEA and BBN can be different. The FMEAs are usually carried out with a small team, whereas the data for BBN require larger sample sizes to allow the calculation of various conditional probabilities.

6.5 DOE (Taguchi method)

The Taguchi method was very effective in identifying the main effects that influence electric, fire and fall hazards. The experiment using the L16 orthogonal array was an efficient way to study many variables (five factors) in 16 runs. Both graphical and statistical analysis showed that training, experience, response to alarm, age and the interaction between training and experience are the most significant factors, and they have the most influence in decreasing the extinguishing time of fire and the percentage of damage. Based on the experimental results, models were developed using multiple regression and ANOVA to predict extinguishing time and percentage of damage as a result of fire.

6.6 Implementing 5S

5S was implemented in various areas and resulted in many benefits, including fewer accidents, fewer mistakes, improved flow, and better use of space; most importantly it improved the overall employees' safety. The implementation was conducted in many steps. Firstly, awareness training was conducted with all employees so that they understood the objectives and the benefits of 5S. Secondly, an audit of the identified areas, namely the TV Studio (Recording Room), movable décor tableaus storage, and the furniture room, was conducted in order to assess the current adherence to 5S - Sorting, Straightening (set in order), Shining (Sweep), Standardise, and Sustaining (Self Discipline). The areas that scored low in the audit assessment were subjected to improvement to raise them to the desired level. Thirdly, corrective actions with target dates and responsibilities were initiated to improve the areas with low scores. Finally, another audit was conducted to assess the effectiveness of the improvement.

6.7 Utilisation of Value Stream Map (VSM)

The Value Stream Map (VSM) was an excellent tool to use for reducing process cycle time, and the application of VSM in this research was very effective. Process VSM was established and value-added and non-value-added activities were identified along with the time spent performing each activity. Also, the potential safety hazards of performing each activity were also identified. Improvement opportunities were identified and were the bases for the future VSM. Employee training was effective and improved efficiency in the following processes: décor preparation, loading and unloading, recording, and doors.

6.8 Applying of Poka-Yoke

Poka-Yoke was an effective tool for minimising mistakes by operators. Since workers are subject to many manual activities, errors may occur. Poka-Yoke was used to minimise these errors by eliminating manual activities and improving performance in the décor processes. Improvements were achieved in the décor process by changing the decoration system to a different layout, where five recording units were established in five separate platforms isolated from other sounds and lights, and by establishing a complete Chroma frame.

6.9 Building Knowledge

Another benefit of this research was building knowledge. Building knowledge is defined as the process of identifying and collecting critical organisational knowledge from employees, documents, programmes, or processes and making it available to use to improve performance. The knowledge, skills and information from other companies and educational institutions were transferred to improve the working conditions in SBC, including employee safety and performance, and to share these best practices across other areas in the organisation. Poka-Yoke was the tool used to transfer the knowledge in order to minimise human errors and improve safety and productivity.

6.10 Awareness and Training programme

The SBC employees work for 24 hours a day at different workplaces that include offices, control rooms, workshops, storages and studios. SBC provides intensive training courses about Safety & Health and LSS. These training courses include:

- Fire extinguishing and evacuation training for all staff
- An introduction of Safety & Health for new employee working in TV studios
- Introduction of DMAIC methods
- 5S Auditing courses
- Material handling courses
- Working at height
- Electrical and Mechanical safety manual to spread awareness to staff
- Full-time safety courses for employees working on productions, including Safety & Health Management Systems and risks assessments
- The significant of age

In this study, age plays an important role in the Health and Safety Management System; employees who are less than forty years old have a significant effect on minimising fire risks and are more effective than others at using a fire extinguisher. They are faster to extinguish fires and to respond to the fire alarm. Finally, age is one of the most influential factors in decreasing the extinguishing time and the percentage of damage.

6.11 Applying the Control Chart

The control chart tool was effective in validating the effectiveness of the improvement activities and in helping to sustain these improvements. The c-chart was the ideal chart for this application since the number of accidents were plotted again time. Control limits were established and used as a basis to monitor the process for out-of-control condition as a result of any assignable causes which might result in more accidents. Any assignable cause was identified and removed.

6.12 Overall Conclusion

Lean Six Sigma has been successfully implemented in a transactional process to enhance the Occupational Health and Safety Management System in the SBC. It was a powerful guide to successfully improve the processes, reduce errors, and minimise safety hazards. The tools that were applied were very effective in helping to identify and eliminate electric, fire and fall hazards' root causes. The research has had an important impact on the company and its employees, with positive outcomes and feedback from both the company's management, the technical experts, and especially the employees.The research improved their safety by reducing electrical, fire and fall risks.

6.13 Contribution to knowledge

Reflecting back on the aim and the objectives of the project, this research has demonstrated that Lean Six Sigma tools are suitable for application in transactional processes in a TV studio. They complement any existing health and safety programmes and the integration of both was very effective in reducing safety hazards such as electric, fire and fall. This research has made the following significant contributions to knowledge:

- Developed a methodology for the integration of both established Health and Safety Management Systems and Lean Six Sigma techniques to identify and control potential hazards and to minimise the accidents in SBC.
- Prevented and reduced safety hazards and risks in SBC by combining cause-and-effect analysis, FMEA, Pareto principles and Bayesian Belief Networks (BNNs), etc.

- Gained deep knowledge of the importance and significance of various factors in the management of the fire hazards using the Taguchi method and Design of Experiment (DOE).
- Used Bayesian Belief Network models to model and simulate the major causes of electric, fire, and fall hazards in SBC, together with sensitivity and what-if analyses.
- Used Statistical Process Control (SPC) to control and continually improve the key process performances in the management of safety hazards.

6.14 Future work

The research limitation was that LSS & OSHMS were only implemented in SBC's studio, which is adapted to Saudi culture by only including male employees.

While the results presented in this thesis demonstrated the effectiveness of the contributions listed above, there are still opportunities to expand on the scope of this thesis. For future research, expansion is recommended to other Six Sigma techniques such as Measurement System Analysis (MSA), and other Lean tools, to expand the area of analysis as well as to enrich the outcomes with more data analysis and evaluation. In addition to that, work can be conducted on building models to act as a benchmark for process optimisation related to industrial fields. Furthermore, it is also recommended to study other areas in systems which have an impact on Health and Safety Management, as well as risk assessments, to develop overall criteria for safety standards. Such a path could further contribute to the literature and previous studies, and would also help to overcome the restrictions and obstacles of this study.

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Publications

- **Details of papers that I have published**

  - Alharthi, A. A., Sharaf, M. A., and Aziz, T., (2014) 'An Integrated Approach Lean Six Sigma and Risk Management in Entertainment and Media Industry', Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management. Bali, Indonesia, January 7 – 9, 2014. Available at: http://iieom.org/ieom2014/pdfs/15.pdf

  - Alharthi, A.A. and Yang, Q., (2014) 'Application of Taguchi Method in Health and Safety (Fire Extinguishing Experiment)', *Journal of Engineering Research and Applications*, 4, (5/2), pp. 37-44. Available at : http://www.ijera.com/papers/Vol4_issue5/Version%202/H45023744.pdf

- **I have prepared these papers:**

  - Applying the combination of FBD, FMEA, Pareto and BBN to assess Electrical, Fire and Fall hazards.
  - Application of VSM and 5S to eliminate wastes and time in the TV programming process.
  - Implementation of Poka-Yoka to improve TV studios in the Saudi Broadcasting Corporation.

APPENDICES

Appendix A : INFORMED CONSENT FORM

I understand that my participation in this study is strictly voluntary and that I may discontinue my participation at any time without prejudice. I understand that the purpose of this study is to assess if implementation of Lean Sigma would reduce fire risks and improve safety processes in media organisations. The research project is titled: Applying Lean Six Sigma to continuously improve safety processes in state run media organisations.

I further understand that any information that is collected from me during this study will be held in the strictest confidence and will not be part of any permanent record. I understand that upon completion of the study, the researcher (Adel Alharthi) will destroy all personal data. However, the analysed findings will be available for my viewing. I am aware that I have not and am not waiving any legal or human rights by agreeing to this participation.

By signing below I verify that I am 18 years of age or older, in good mental and physical condition, and that I agree to and understand the conditions listed above.

Signature ______________________________

Date ______________________________

Please fax or mail completed form to:

Adel Alharthi

Email:

Telephone:

Appendix B: Questionnaire/ Interview

1. **As an organisation have you recognised the importance of managing health and safety by applying Lean Six Sigma?**

- Yes. We understand that applying Lean Sigma will eliminate unnecessary process steps in the safety system. However, we are yet to implement the concept.
- I feel that we are reluctant to apply it immediately because it requires changing the organisation layout to improve process flow in our safety system.
- We are looking for efficiencies in workflow, document processing, and reducing the number of steps in the process. In fact, our aim is to enhance our ability to protect the work environment by being able to provide more time and resources on employee safety.
- We are now committed to applying Lean Six Sigma to solve problems caused by health and safety hazards.

2. **What is your current safety performance? Is it relative to your overall health and safety aims and objectives?**

- Our current safety performance is poor. It has affected health and safety as is evident from the increasing number of accidents.
- We do not have a typical preventive maintenance programme. It is also not based on regular inspections to find deficiencies.
- Maintaining safety requires our employees to make available more time for training sessions. However, our current safety performance is seriously affected by employees who spend less number of hours on training sessions. Also, we have a shortage of qualified personnel for maintaining quality and safety. We therefore feel that by implementing Lean Six Sigma we may be able to ensure safety as it requires few qualified personnel.
- Our current safety performance is poor and we hope to improve it by decreasing the variability of processing times.

3. **How is your organisation controlling risks at present?**

- We have certain controls in place but are not confident that we will be able to control risks. However, we hope to use Lean Sigma tools and techniques in the near future to control risks in a better manner.

4. **Are you able to manage health and safety effectively? If so is it consistent?**

- I don't think we are able to effectively and consistently manage risks caused by hazards such as fire, fall and electrical. Ideally our services should develop a training framework so that our maintenance personnel are skilled and also be proactive.

5. **What are the major factors that contribute to unsafe behaviour and unhealthy working condition at the workplace and in the organisation?**

- The factors are inadequate training, which effect of employees' experience , disorganised area, décor problems and human error, which cause fire, fall and electrical hazards.

6. **Have you deployed an effective health and safety management system? If so is it in place across all parts of the organisation?**

- Yes we have deployed a safety system but it is not effective. It is in place in certain sections of the organisation. We need Lean Six Sigma consultants to apply new tools and techniques which can be used to avoid the problems faced currently.

7. **What are the risks associated with our activities? What is the significance of the risks (high/low)?**

Risk	Severity	Occurrence	Detectability
Fire	**High**	**High**	**Low**
Fall	**High**	**High**	**Low**
Electrical	**High**	**High**	**Low**

8. **Do you think that by applying Lean Sigma the organisation can eliminate all risks?**

- Yes. I feel that by using Lean Six Sigma, we can get to the data that tells us where the risks are.

- Lean Six Sigma principles can help unify all employees. It will helping everyone to understand the common goals that an organisation must set out to achieve in order to build a better safety system that places the employee at the centre of its focus.

9. What information (on health and safety) is available to assure that throughout the organisation, arrangements are in place at present to control risks?

- The information is attached. (Appendix)

10. Do you agree to the following statements regarding the application of Lean Six Sigma to improve safety in workplaces?

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
A standard problem solving process or root cause analysis is important in work places	✓				
A standard continuous improvement methodology is important for the organisation	✓				
By implementing Lean Six Sigma risks can be mitigated and safety issues can be solved	✓				

11. **Does culture play a supportive role in application of Lean Six Sigma**?

We expect resistance from employees but we have to transform the culture to support Lean Six Sigma.

12. **Please specify failure modes, causes and effects of the following hazards (Fire, Fall and Electrical) in your organisation. (Brainstorming session for FMEA)**

Risk	**Potential Failure mode**	**Causes**	**Effect**
Fire			
Fall			
Electrical			

Appendix C : Safety & Health Procedures

Ministry of Culture and Information, Saudi Arabia

Ministry of Culture & Information
Safety and Health Procedures
Accident Cause Analysis Worksheet

Location:

ACCIDENT ANALYSIS PERIOD: FROM ______________________TO

ACCIDENT CAUSES

UNSAFE ACTS	**No.**	***% of Tota**	**UNSAFE CONDITIONS**	**No.**	***% of Tota**
FATIGUE			SLIPPERY FLOORS/STAIRS/AREAS		
IMPROPER LIFTING			DEFECTIVE FLOORS/STAIRS/AREAS		
IMPROPER USE OF TOOLS OR EQUIPMENT			POOR HOUSEKEEPING		
REPETITIVE MOTION			DEFECTIVE TOOLS OR EQUIPMENT		
COLLISION			ELECTRICAL SHORTCIRCUITS		
OTHERS			OTHERS		
TOTALS		TOTALS			

*TOTAL NUMBER OF CAUSES-UNSAFE ACTS & UNSAFE CONDITIONS

INJURY SUMMARY

Injury	***Major***	***Minor***	***Total***
BRUISES EYES			
CUTS & PUNCTURES HEAD			
STRAINS TRUNK			
EYE INJURIES ARMS			
FRACTURES HANDS			
DISMEMBERMENTS FINGER			
DERMATITIS LEGS			
BURNS FEET			
SLIVERS TOES			
MULTIPLE OTHER:			
FATALITIES			
OTHER:			

Special Remarks

Months	***Injuries Recorded***		***Lost working days***	
	Per month	Cum	Per month	Cum
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
TOTAL				

Prepared by: Signature:

Dated: Stamp of official:

Appendix D : BBN Questionnaire

Please choose whether each of the below sources of risk exists in the media industry. You can choose more than one.

1. In your opinion, which of the following risk sources can cause Electrical Hazards?			
☐ **Yes**		☐ No	
Inadequate Training	Lack of experience	Disorganised Area	Overheating
❑ Yes	❑ Yes	❑ Yes	❑ Yes
❑ No	❑ No	❑ No	❑ No
Overload	Old Equipment	Bad Maintenance	Bad Connecting
❑ Yes	❑ Yes	❑ Yes	❑ Yes
❑ No	❑ No	❑ No	❑ No
2. In your opinion, which of the following risk sources can cause Fire Hazards?			
☐ **Yes**		☐ No	
Inadequate Training	Lack of experience	Disorganised Area	Overheating
❑ Yes	❑ Yes	❑ Yes	❑ Yes
❑ No	❑ No	❑ No	❑ No
Lack of Detection	Lack of Protection	Bad Maintenance	Bad Connecting
❑ Yes	❑ Yes	❑ Yes	❑ Yes
❑ No	❑ No	❑ No	❑ No
3. In your opinion, which of the following risk sources can cause Fall Hazards?			
☐ **Yes**		☐ **No**	
Inadequate Training	Lack of experience	Disorganised Area	Handling Problem
❑ Yes	❑ Yes	❑ Yes	❑ Yes
❑ No	❑ No	❑ No	❑ No
Décor Problems	Tool problems	Bad Maintenance	Safety inspection Weakness
❑ Yes	❑ Yes	❑ Yes	❑ Yes
❑ No	❑ No	❑ No	❑ No

BBN for Fire Hazards causes before improvement- Data and Calculation- Sample A1:

Ina T		Total
Yes	**No**	
.92(46/50)	**.08(4/50)**	**50**

Ina T	LE		Total
	Yes	**No**	
Yes	**.761 (35/46)**	**.239(11/46)**	**46**
No	**.5 (2/4)**	**.5 (2/4)**	**4**
Total	**74% (37)**	**13**	**50**

P(LE) = p(LE | inT) * p(inT)+
p(LE| ~inT) * p(~inT)

P(LE) = (0.761*0.92)+ (0.5 * 0.8)

P(LE) = 0.74

Ina T	DA		Total
	Yes	**No**	
Yes	**.739(34/46)**	**.261(12/46)**	**46**
No	**.5 (2/4)**	**.5 (2/4)**	**4**
Total	**72% (36)**	**14**	**50**

P(DA) = p(DA | inT) * p(inT)+
p(DA| ~inT) * p(~inT)

P(DA) = (0.739*0.92)+ (0.5 * 0.8)

P(DA) = 0.72

InaT	LE	L_DET		Total
		Yes	**No**	
Yes	**Yes**	**.857(30 /35)**	**.143(5/ 35)**	**35**
	No	**.182 (2/11)**	**.818 (9/11)**	**11**
No	**Yes**	**.5 (1/2)**	**.5 (1/2)**	**2**
	No	**.5 (1/2)**	**.5 (1/2)**	**2**
Total		**(34)**	**16**	**50**

P(L_DET) = p(L_DET | inT,LE) * p(inT) * p(LE) + p(L_DET| ~inT,E) * p(~inT) * p(LE) + p(L_DET | inT~LE) * p(inT) * p(~LE) + p(L_DET| ~inT~LE) * p(~inT) * p(~LE)

P(L_DET) = 0.857 * 0.92 * 0.74 + 0.5 * 0.08 * 0.74 + 0.182 * 0.92 * 0.26 + 0.5 * 0.08 * 0.26

P(L_DET) = 0.583+0.03+0.044+ 0.01 = 0.67

InaT	LE	DA	B_CON		Total
			Yes	**No**	
Yes	**Yes**	**Yes**	**.969(31/ 32)**	**.031(1/ 32)**	**32**
		No	**0 (0/3)**	**1 (3/3)**	**3**
	No	**Yes**	**1 (2/2)**	**0 (0/2)**	**2**
		No	**0 (0/9)**	**1 (9/9)**	**9**
No	**Yes**	**Yes**	**1 (1/1)**	**0 (0/1)**	**1**
		No	**0 (0/1)**	**1 (1/1)**	**1**
	No	**Yes**	**1 (1/1)**	**0 (0/1)**	**1**
		No	**0 (0/1)**	**1 (1/1)**	**1**
Total			**(35)**	**15**	**50**

P(B_CON) = p(B_CON |inT,LE,DA) * p(inT) * p(LE) * p(DA) +
p(B_CON | inT,LE,~DA) * p(inT) * p(LE) * p(~DA) +
p(B_CON | inT,~LE,DA) * p(inT) * p(~LE) * p(DA) +
p(B_CON | inT,~LE,~DA) * p(inT) * p(~LE) * p(~DA) +
p(B_CON |~ inT,LE,DA) * p(~inT) * p(LE) * p(DA) +
p(B_CON |~ inT,LE,~DA) * p(~inT) * p(LE) * p(~DA) +
p(B_CON |~ inT,~LE,DA) * p(~inT) * p(~LE) * p(DA) +
p(B_CON |~ inT,~LE,~DA) * p(~inT) * p(~LE) * p(~DA)

P(B_CON) = 0.969 * 0.92 * 0.74 * 0.72 +
0 * 0.92 * 0.74 * 0.28 +
1 * 0.92 * 0.26 * 0.72 +
0 * 0.92 * 0.26 * 0.28 +
1 * 0.08 * 0.74 * 0.72 +
0 * 0.08 * 0.74 * 0.28 +
1 * 0.08 * 0.26 * 0.72 +
0 * 0.08 * 0.26 * 0.28

P(B_CON) = 0.475+0+0.172+ 0+0.043+0+0.015+0= 0.70

InaT	L_DET	LE	L_PROT		Total
			Yes	**No**	
Yes	**Yes**	**Yes**	**.9 (27/30)**	**.1 (3/30)**	**30**
		No	**1 (2/2)**	**0 (0/2)**	**2**
	No	**Yes**	**0 (0/5)**	**1 (5/5)**	**5**
		No	**0 (0/9)**	**1(9/9)**	**9**
No	**Yes**	**Yes**	**0 (0/1)**	**1 (1/1)**	**1**
		No	**1 (1/1)**	**0 (0/1)**	**1**
	No	**Yes**	**1 (1/1)**	**0 (0/1)**	**1**
		No	**0 (0/1)**	**1 (1/1)**	**1**
Total			**(31)**	**(19)**	**50**

L_PROT	L_Det	OV_Heat		Total
		Yes	**No**	
Yes	**Yes**	**.667(20/30)**	**.333(10/30)**	**30**
	No	**1 (1/1)**	**0 (0/1)**	**1**
No	**Yes**	**.25(1/4)**	**.75(3/4)**	**4**
	No	**.067(1/15)**	**.933(14/15)**	**15**
Total		**46% (23)**	**27**	**50**

L_PROT	Flam_Mat		Total
	Yes	**No**	
Yes	**.71(22/31)**	**.29(9/31)**	**31**
No	**.263(5/19)**	**.737(14/19)**	**19**
Total	**54% (27)**	**23**	**50**

B_CON	**Flam_Mat**	OV_Heat	Fire caused hazards		Total
			Yes	**No**	
Yes	**Yes**	**Yes**	**.25(4/16)**	**.75 (12/16)**	**16**
		No	**.2(1/5)**	**.8 (4/5)**	**5**
	No	**Yes**	**.2 (1/5)**	**.8 (4/5)**	**5**
		No	**0 (0/9)**	**1(9/9)**	**9**
No	**Yes**	**Yes**	**0 (0/0)**	**1(1/1)**	**1**
		No	**.2 (1/5)**	**.8(4/5)**	**5**
	No	**Yes**	**0 (0/1)**	**1 (1/1)**	**1**
		No	**.375(3/8)**	**.625(5/8)**	**8**
Total			**10**	**40**	**50**

Electricity causes Hazards BBN before LSS – sample (A2)

Ina T		Total
Yes	**No**	
0.9(45/50)	**.1(5/50)**	**50**

Ina T	LE		Total
	Yes	**No**	
Yes	**.778(35/45)**	**.222(10/45)**	**45**
No	**.6(3/5)**	**.4 (2/5)**	**5**
Total	**38**	**12**	**50**

Ina T	DA		Total
	Yes	**No**	
Yes	**.711(32/45)**	**.289(13/45)**	**45**
No	**.6(3/5)**	**.4 (2/5)**	**5**
Total	**35**	**15**	**50**

InaT	LE	OLD_EQUIP		Total
		Yes	**No**	
Yes	**Yes**	**.829(29/35)**	**.171(6/35)**	**35**
	No	**.1(1/10)**	**.9 (9/10)**	**10**
No	**Yes**	**1 (3/3)**	**0 (0/3)**	**3**
	No	**0 (0/2)**	**1 (2/2)**	**2**

Total	33	17	50

InaT	LE	DA	B_CON		Total
			Yes	**No**	
Yes	**Yes**	**Yes**	**.968(30/31)**	**.032(1/31)**	**31**
		No	**0 (0/4)**	**1 (4/4)**	**4**
	No	**Yes**	**1 (1/1)**	**0 (0/1)**	**1**
		No	**0 (0/9)**	**1 (9/9)**	**9**
No	**Yes**	**Yes**	**1 (2/2)**	**0 (0/2)**	**2**
		No	**0 (0/1)**	**1 (1/1)**	**1**
	No	**Yes**	**1 (1/1)**	**0 (0/1)**	**1**
		No	**0 (0/1)**	**1 (1/1)**	**1**
Total			**34**	**16**	**50**

InaT	OLD_EQUIP	**LE**	BM		Total
			Yes	**No**	
Yes	**Yes**	**Yes**	**.897(26/29)**	**.103(3/29)**	**29**
		No	**1 (1/1)**	**0 (0/1)**	**1**
	No	**Yes**	**0 (0/6)**	**1 (6/6)**	**6**
		No	**0 (0/9)**	**1 (9/9)**	**9**
No	**Yes**	**Yes**	**.5 (1/2)**	**.5 (1/2)**	**2**
		No	**1 (1/1)**	**0 (0/1)**	**1**
	No	**Yes**	**1 (1/1)**	**0 (0/1)**	**1**
		No	**0 (0/1)**	**1 (1/1)**	**1**
Total			**30**	**20**	**50**

BM	OLD_EQUIP	OV_Heat		Total
		Yes	**No**	
Yes	**Yes**	**.69(20/29)**	**.31(9/29)**	**29**
	No	**1 (1/1)**	**0 (0/1)**	**1**
No	**Yes**	**.25(1/4)**	**.75(3/4)**	**4**
	No	**.062(1/16)**	**.938(15/16)**	**16**
Total		**23**	**27**	**50**

BM	OV_Load		Total
	Yes	**No**	
Yes	**.7(21/30)**	**.3(9/30)**	**30**
No	**.25(5/20)**	**.75(15/20)**	**20**
Total	**26**	**24**	**50**

B_CON	OV_Load	OV_Heat	Electricity caused hazards		Total
			Yes	**No**	
Yes	**Yes**	**Yes**	**.25(4/16)**	**.75 (12/16)**	**16**
		No	**.25(1/4)**	**.75(3/4)**	**4**
	No	**Yes**	**.2(1/5)**	**.8(4/5)**	**5**
		No	**0 (0/9)**	**1 (9/9)**	**9**
No	**Yes**	**Yes**	**0 (0/1)**	**1 (1/1)**	**1**
		No	**.2 (1/5)**	**.8 (4/5)**	**5**
	No	**Yes**	**0 (0/1)**	**1 (1/1)**	**1**
		No	**.111(1/9)**	**.889(8/9)**	**9**
Total			**23**	**27**	**50**

Appendix E : 5S auditing checklist

AREA:					DATE:	
Manager				**Supervisor**		
Scoring ▼	**SORT**	**SET IN ORDER**	**SHINE**	**STANDARDISE**	**SUSTAIN**	**TOTAL**
Total Score						
# of Questions						
Average Score						

SCORING GUIDELINES					
0	**1**	**2**	**3**	**3.5 (4)**	**4.5 (5)**
ZERO EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MINIMUM ACCEPTABLE LEVEL	ABOVE AVERAGE RESULTS (3 AUDITS)	OUTSTANDING RESULTS (6 AUDITS)

Category	Score	Observation	Due date	Responsible
SORT				
1. Area is free of unnecessary clutter.				
2. Only the required tools are in the work area.				
3. Only the required materials are in the work area.				
4. All required Personal Protective Equipment is in work area.				
5. Area is free of slip/trip/fall hazards.				

STRAIGHTEN				
1. Locations for tools and equipment are clearly marked and labelled				
2. Frequently used items are within easy reach of work area.				
3. All dormant or excess items are stored properly and out of the way.				
4. Aisles are straight, clear, and well-marked.				
5. Visual controls highlight groups, workflow, equipment, & process.				
SHINE				
1. Everything in workspace is "like new"				
2. No dust or dirt anywhere.				
3. Trash and recycle bins are emptied daily				
4. No painted items are chipped or worn.				
5. All cleaning equipment is stored properly and readily available.				
STANDARDISE				
1. Checklists for 5s activities are available and followed.				
2. Results of previous audit are posted in area.				
3. All areas for improving from previous audit are completed.				
4. Last 5s assessment was performed less than a month ago.				

5. All charts and metrics in the area are current.				
SUSTAIN				
1. CEO or general manager has participated in one of last 3 audits.				
2. Time and resources are given to 5s activities in area				
3. Recognition is given to teams that are involved and excel in 5s activities.				
4. An average score of at least 4.0 was achieved in the audits in the last 3 months.				
5. An average score of at least 4.0 was achieved in the audits in the last 6 months.				

5S auditing checklist

AREA:					DATE:	
Manager				Supervisor		
Scoring ▼	SORT	SET IN ORDER	SHINE	STANDARDIZE	SUSTAIN	TOTAL
Total Score						
# of Questions						
Average Score						

SCORING GUIDELINES					
0	1	2	3	3.5 (4)	4.5 (5)
ZERO EFFORT	SLIGHT EFFORT	MODERATE EFFORT	MINIMUM ACCEPTABLE LEVEL	ABOVE AVERAGE RESULTS (3 AUDITS)	OUTSTANDING RESULTS (6 AUDITS)

Category	Score	Observation	Due date	Responsible
SORT				
1. Area is free of unnecessary clutter.				
2. Only the required tools are in the work area.				
3. Only the required materials are in the work area.				
4. All required Personal Protective Equipment is in work area.				
5. Area is free of slip/trip/fall hazards.				
STRAIGHTEN				
1. Locations for tools and equipment are clearly marked and labeled				
2. Frequently used items are within easy reach of work area.				
3. All dormant or excess items are stored properly and out of the way.				
4. Aisles are straight, clear, and well-marked.				
5. Visual controls highlight groups, workflow, equipment, & process.				
SHINE				
1. Everything in workspace is "like new"				
2. No dust or dirt anywhere.				
3. Trash and recycle bins are emptied daily				
4. No painted items are chipped or worn.				
5. All cleaning equipment is stored properly and readily available.				
STANDARDIZE				
1. Checklists for 5s activities are available and followed.				
2. Results of previous audit are posted in area.				
3. All areas for improving from previous audit are completed.				
4. Last 5s assessment was performed less than a month ago.				
5. All charts and metrics in the area are current.				
SUSTAIN				
1. CEO or general manager has participated in one of last 3 audits.				
2. Time and resources are given to 5s activities in area				
3. Recognition is given to teams that are involved and excel in 5s activities.				
4. An average score of at least 4.0 was achieved in the audits in the last 3 months.				
5. An average score of at least 4.0 was achieved in the audits in the last 6 months.				

Appendix F : SBC Feedback

To whom it may concerns,

As a result of Adel's work of integrating Lean six sigma with our Health and safety System at Saudi Broadcast Corporation (SBC), safety, measured by the number of incidents occurred on monthly bases have been reduced significantly. The Management and the employees at Saudi Broadcast Corporation (SBC) are thankful and delighted for his effort and the utilization of Lean Six Sigma. Integration of Lean Six Sigma with Health and safety System was a tremendous success and we will be using the tools for years to come.

Chief Engineer

Ahmed Alshalawy