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An application of lean six sigma techniques to accelerate the implementation of Kaizen in the film packaging industry

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by Matshidiso Moso

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Declaration

I hereby declare that this study is my own work and does not contain material that has been published previously by another student or researcher. This material has not been accepted previously for the awarding of any degree at Durban University of Technology or any other educational institution. Furthermore, I declare that the academic content of this thesis is my own work. The support given and contribution made by the company used in the study has been clearly acknowledged in the thesis.

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Matshidiso Moso (20929139)

Date: _____13 January 2021_____

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Abstract

The integration of lean six sigma techniques in manufacturing results in substantial improvement and hence a more profitable organization. The case study company is based in South Africa and specialises in manufacturing plastic film, which uses thin micron plastic for food packaging. The main goal of this research was to accelerate the rate of kaizen implementation by utilizing lean six sigma techniques in order to construct a semi-automated model. Lean six sigma is comprised of various problem-solving techniques. In this case study, 5Whys was combined with Ishikawa to construct a semi-automated model for an effective defect trouble shooting closure system. Defect trouble shooting system is also called a “non-conformance closure system”.

It was evaluated that the procedure of non-conformance closure at the company was inadequate; this was identified as a major finding during an external ISO audit. An opportunity to utilize lean techniques was identified and implemented in order to satisfy the objectives of this research. The first objective was to define the requirements of ISO standards in order to find a suitable system that could be used. Defining the requirements was key for the researcher to get an idea of how the model should be constructed to suit ISO standard requirements. The second objective was to evaluate the current method and find the root cause of the problem; this objective highlighted all the possible causes that had resulted in an inadequate procedure for non-conformance closure.

The third objective was to construct a model by integrating lean techniques that matched ISO standards. This objective was implemented in order to satisfy the research goals; a semi-automated model resulted in a catalyst for continual improvement. The fourth objective was to implement the semi-automated model on each non-conformance that was raised and the fifth objective was to reflect by monitoring and recording the results from the semi-automated model. This method resulted in a smooth flow system of non-conformance closure; the major finding closure was accepted after the auditors monitored the new semi-automated method. Automated non-conformance software, which integrates any system that needs corrective action, was recommended, and seven types of waste were recommended for further analysis. This semi-automated model can be used as a future programme parameter for completing an automated system to resolve non-conformances.

Table of Contents

List of Acronyms

BSC	Balance Score Card
CAPA	Corrective Action Plan
CAR	Corrective Action Report H
DMAIC	Define, Measure, Analyse, Improve, Control
ERP	Enterprise Resource Planning
EVSM	Environmental Value Stream Mapping
ISO	International Standards Organization
NCR	Non-conformance Report
NCI	Non-conformance Information
OH&S	Occupational Health and Safety
OP	Operations Planning
PDCA	Plan Do Check Act
QA	Quality Assurance
SMD	Single Minute Exchange of Die
TPM	Toyota Production systems
TQM	Total Quality Management
VSM	Value Stream Mapping
VOC	Voice of Customer
WIP	Work In Progress

List of Tables

List of Figures

CHAPTER 1 : INTRODUCTION

1.1 Introduction

The food film packaging industry is one of the essential manufacturing sectors that specialises in converting plastic granules into thin micron plastic film. The film manufacturing process recipe is not complicated compared to other manufacturing production lines even though it consumes a great deal of energy. Today plastic food packaging is the most preferable method since plastic is recyclable and has less environmental impact. This presents a challenge for the film packaging industry to continually improve their system in order to maintain food safety and quality standards. The case study company is a kaizen philosophy-driven business. Kaizen philosophy is a Japanese philosophy which typically drives any system as a catalyst to accelerate the rate of innovation within a business, leading to a high productivity rate with zero defects and thus a profitable organization [1].

Lean manufacturing techniques complement kaizen philosophy by stimulating improvement. Kaizen techniques have been successfully used to identify areas needing improvement in studies done in various sectors and industries and sectors such as the automobile and manufacturing industries and the hospitality, and health-care sectors as well as energy studies and assembly lines to name a few [2].

This thesis focuses on accelerating the rate of kaizen implementation in a film packaging business by utilizing the Ishikawa and 5Whys analytical methods. This chapter introduces the existing lean six sigma tools and techniques, the problem statement, the aim of the study and its importance, as well as the structure of the dissertation.

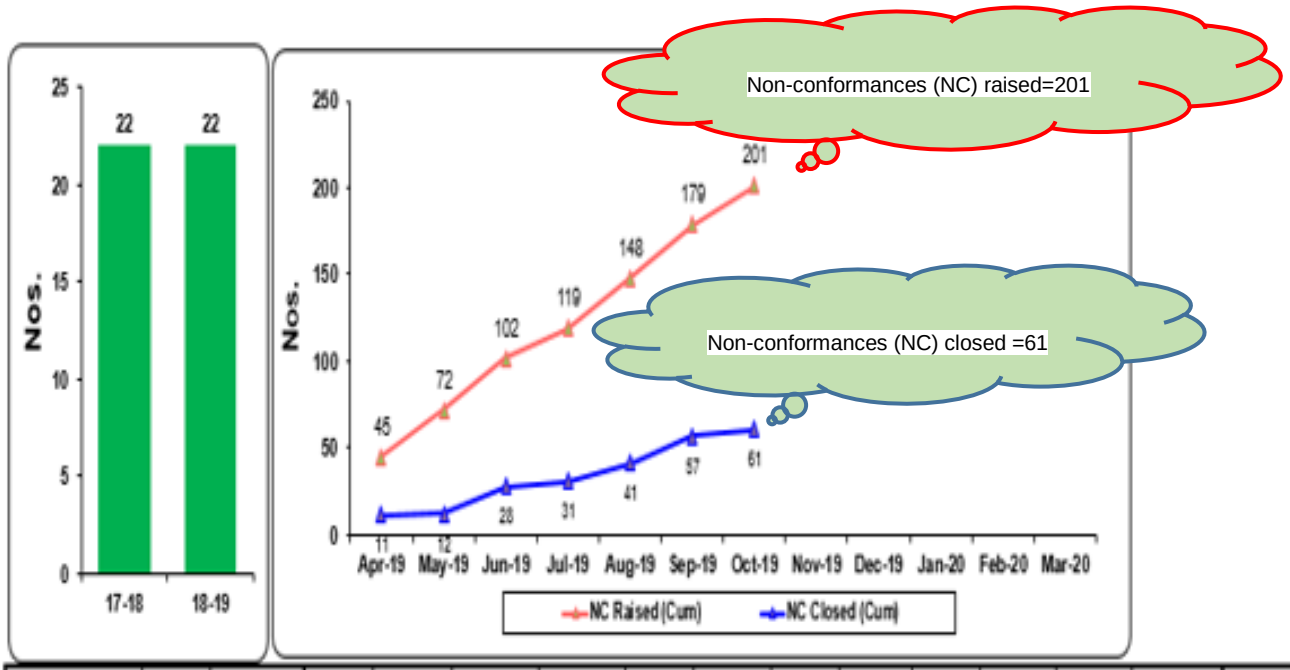
1.2 Problem statement

The research is about applying lean six sigma techniques in order to accelerate kaizen implementation. It had been found that one of the challenges facing the film manufacturing business was to find a proper method of controlling non-conformance status. The total number of non-conformances (defects) raised had been steadily increasing which had resulted in a low level of compliance leading to a lack of innovation. The business had also been struggling to comply with international standards, which had placed the business at risk for credit loss on ISO 9001 certification.

Currently 201 non-conformances had been raised and 61 closed which left 140 pending non-conformances in this study's film production case study. Figure 1.1 illustrates the inconsistency of non-conformance closure: some were older than 90 days and others even older.

According to the previous ISO 9001 audit in Appendix 2, it was noted that there was an inadequate procedure for closing raised non-conformances. There was no tool in place to analyse the cause of the problem and there was inconsistency in the adherence to the proposed closure dates. It was also noted that some findings had been open for a period of 10 months, which is almost a year. This was a major problem for the business, which indicated that there was a need to apply lean tools to generate continuous improvement.

Below is a graph illustrating the monthly follow-up of closure for raised findings, It was found that 201 Non-conformances were raised and 61 non-conformances were closed which clearly shows that there is an inconsistency in terms of addressing issues that has been raised hence 140 non-conformances remained opened.



PFB	17-18	18-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	
NCR History	22	22													
NC Raised (Cum)			**45**	**72**	**102**	**119**	**148**	**179**	**201**						
NC Raised			32	27	30	17	29	31	22						
NC Closed (Cum)			**11**	**12**	**28**	**31**	**41**	**57**	**61**						
NC Closed			1	2	16	3	10	16	4						
YTD															

Figure 1.1: Non-conformance status for closure

Source: Developed by author

1.3 Aim of the study

The case study company was not adhering to international standards, thus there was a low rate of kaizen implementation. The aim of this research was to develop a semi-automated model to accelerate kaizen implementation by implementing an effective system of analysing and closing raised non-conformances.

1.4 Research objectives

The specific objectives were:

- To evaluate the quality of non-conformances in terms of adherence to international standards
- To measure the current situation, finding the root causes for the non-adherence and illustrating the non-conformances raised
- To develop a semi-automated model for non-conformance closure, hence process enhancement
- To demonstrate an application of one of the non-conformances in the case study company's production.

1.5 Research methods

The research was quantitative. The study was carried out using DMAIC which is a lean six sigma tool.

- D (Define) - The current situation was defined using an external audit report where the problem statement was raised as a major finding. For further analysis the current method that had resulted in failure to adhere to International Standards was investigated and defined using Ishikawa so as to understand the problem.
- M (Measurements) - A spreadsheet report with non-conformances raised in the previous months was created and a graph plotted to summarise closures for each month.
- A (Analysis) – An Excel semi-automated model was constructed using Ishikawa, 5Whys analysis and International Standard requirements.
- I (Installation) - The model was implemented, an Operating Procedure was issued and the process owners would be trained.
- C (Control) - The model would be linked to a non-conformance spreadsheet report to indicate the status of closure.

1.6 Significance of the study

The case study company has been in South Africa for seven years. As it was still new in the country, it was in the interests of the business to strive to be the best producer of plastic film. In order to achieve this goal, the company had to comply with International Standards of approval. Using lean manufacturing techniques and kaizen philosophy, the business could substantially improve its production process.

1.7 Limitations

The main objective of this study was to accelerate the rate of kaizen by utilizing lean principles. Even though the semi-automated model was constructed for a non-conformance closure system which complements the rate of increase of kaizen implementation, it is worth noting that customer complaints and supplier non-conformance options were not included in the model design.

1.8 Dissertation format

- Chapter 1: Introduction:

This chapter gives a clear outline of the study. It helps the reader to understand the problem statement and the objectives of the study.

- Chapter 2: Literature review

Chapter two presents the Literature review which looked at relevant studies to assist in achieving the objectives of the study.

- Chapter 3: Research methodology

Chapter three details the lean technique methodology (DMAIC) used to solve the research problem.

- Chapter 4: Case study and company background

Chapter four presents an overview of the company process and how the non-conformances were being dealt with.

- Chapter 5: Results and simulation

Chapter five presents the trials and implementation of the corrective action plan model.

- Chapter 6: Conclusion and recommendations

Chapter six concludes the thesis and makes recommendations for further improvements on the semi-automated model

1.9 Conclusion

Kaizen philosophy has become a valuable tool for profitable organizations to utilize. This thesis will enable the reader to conclude that there is a relationship between kaizen philosophy and lean principles. This study is about the evaluation of lean principles flexibility to accelerate the rate of kaizen implementation in the film packaging industry. In the next chapter the work that has been done by other researchers will be evaluated to assist in achieving the objectives of this study.

CHAPTER 2 : LITERATURE REVIEW OF APPLICATION OF LEAN TECHNIQUES

2.1 Introduction

Kaizen philosophy is a catalyst that combines small value-adding activities into substantial profitable impact, leading to successful businesses with an emphasis on the effective use of lean manufacturing techniques [3]. This chapter reviews the adaptation of lean techniques by successful businesses and presents models for process enhancement.

2.2 Introduction to lean six sigma tools and techniques

Below is an introduction to the lean techniques, which include Ishikawa, Kaizen philosophy, Deming's PDCA cycle, single minute's exchange of Die, Kanban system, Pokayoke, Jidoka, Value Stream Mapping, Heijunka (Level production) and Lean Supply Chains.

2.3 Kaizen philosophy

The word kaizen is a Japanese term meaning 'change for the good by continually improving [3]. Kaizen is composed of different strategies of continuous improvement below figure is a kaizen umbrella with elements of focus deferent kaizen, below kaizen umbrella shows a list of kaizen emphasis

Figure 2.1: Kaizen umbrella

Source: [6]

Kaizen is the philosophy of a culture of continuous improvement and was invented by the president of the Corporate Cambridge Masaaki Imai in 1986 [4]. Kaizen is a successful management culture that most profitable organizations use; for example, a study to eliminate losses by utilizing lean principles and kaizen philosophy was conducted in Valeo Mioveni. Kaizen can be defined as the total involvement of employees to continually improve operations [5]. Ivana, Miroslava and Branca (2019) described kaizen as a device consisting of a circular canopy which covers a number of different Japanese problem solving methods [6]. Figure 2.1 is a diagram illustrating the Japanese concept of kaizen.

2.4 DMAIC process

DMAIC (Define, Measure, Analyse, Improve, and Control) is a systematic approach that one can apply to generate continuous improvement. Below is an illustration of each phase [7].

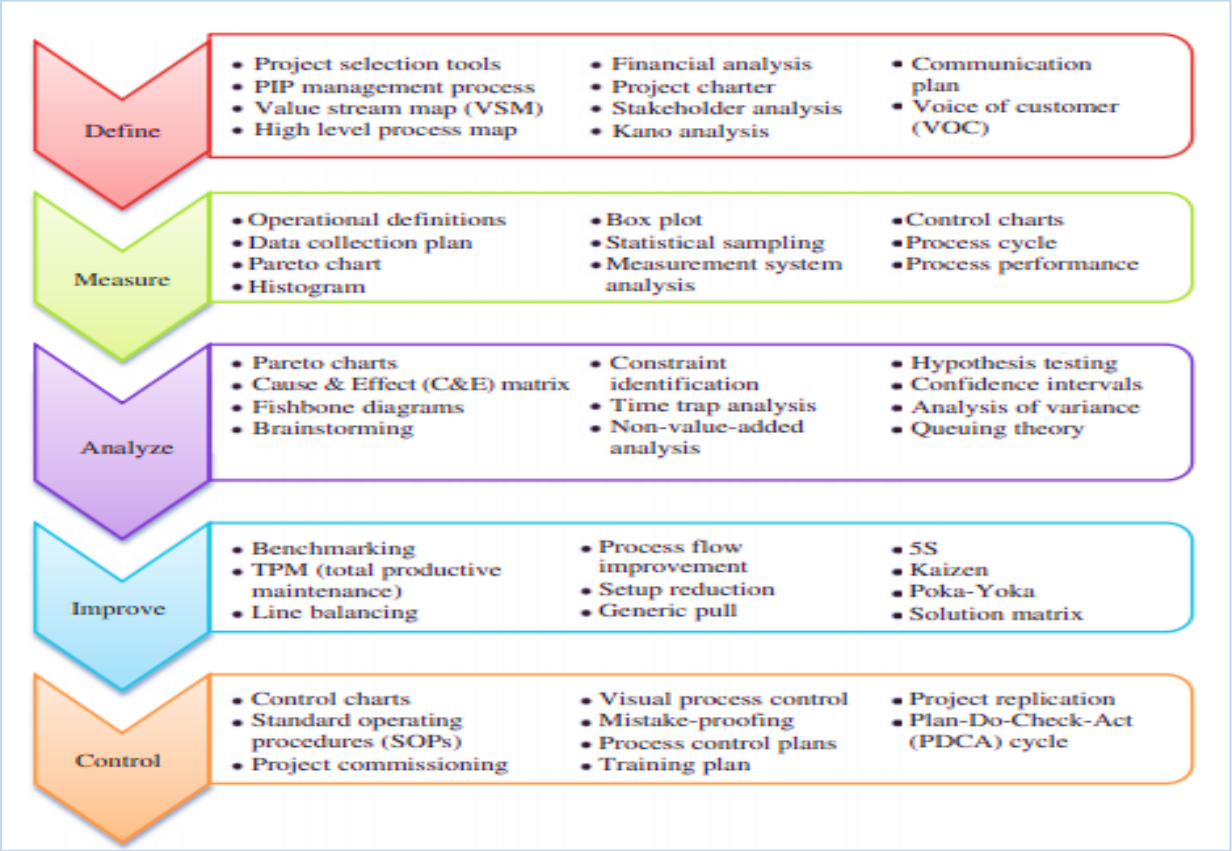


Figure 2.2: Illustration of the DMAIC process

Source: [7]

2.5 Deming's PDCA cycle

It has been established that kaizen is not just a philosophy; it is an application of the Plan, Do, Check, Act (PDA) cycle [8]. The PDCA cycle was invented in the 1920s by Walter A. Shewart and has been implemented by William Edward Deming since the 1950s in Japan, and is more commonly known as the Deming cycle. The purpose of the PDCA cycle is to involve top management in the cycle of continuous improvement [9]. The PDCA cycle complements the effective use of lean tools, for example, Garza-Reyes, Romero, Govindan, Cherrafi and Ramanathan (2018) developed a strategic plan by using the PDA cycle to conduct Environmental Value Stream Mapping. Figure 2.3 illustrates the four stages used [10].

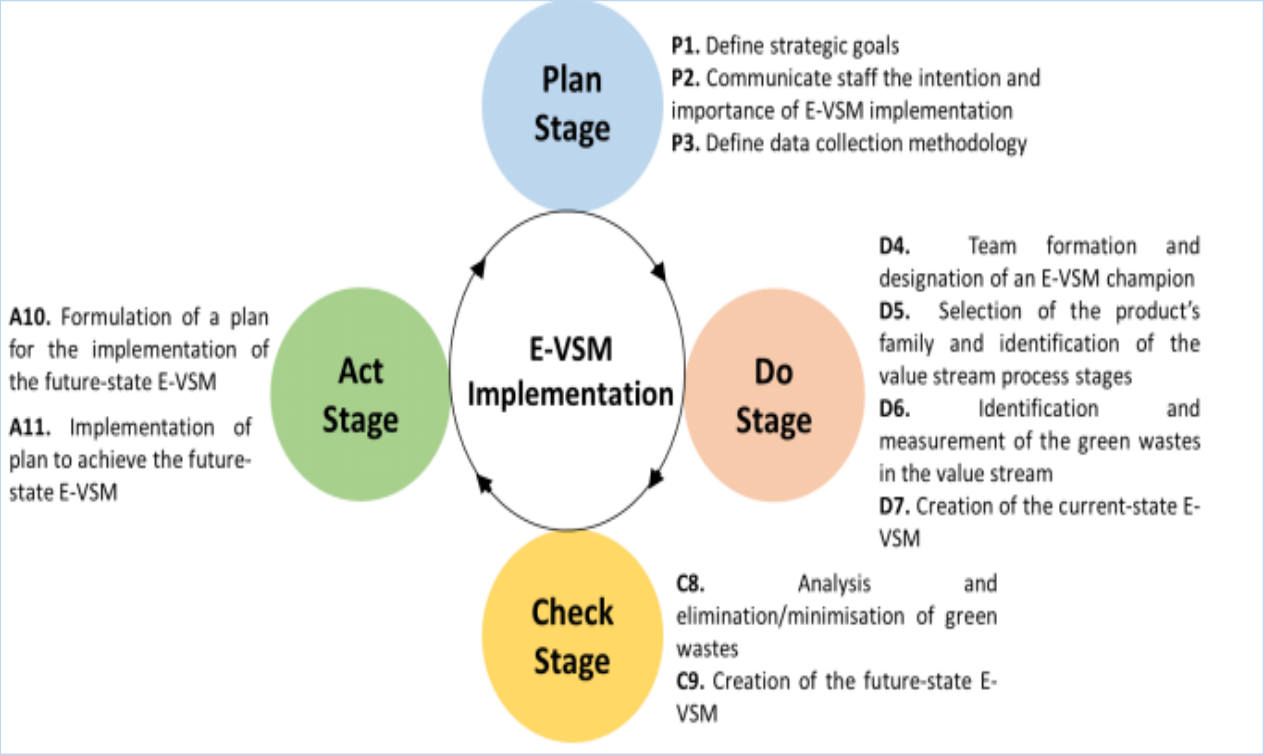


Figure 2.3: Illustration of the PDCA cycle

Source: [10]

2.6 Single Minute Exchange of Die (SMED)

Single Minute Exchange of Die is also known as a quick change-over tool that was invented by Shigeo Shingo who created the Toyota Production Systems [11]. This highly effective tool was applied to eliminate idle time during the car body moulding change-over. The SMED tool is a flexible tool, which can be applied in any change-over process; hence it was applied in the processing of plastic bottles and resulted in the elimination of idle time. This technique is divided into seven steps, namely, observing, analysing set-up time, eliminating searching losses, determining internal and external activities, converting internals to externals, Kaizen on internal activities, Kaizen on external activities and standardization [12].

2.7 Kanban system

The Kanban system is a system that is mainly applied in the manufacturing industry as a job card system; however, it has been established that Kanban is a method that links to lean and just in time (JIT) production. In addition, it is an effective tool that enables one to track and trace work easily. It has been further established that the Kanban system creates a smooth flow in the work process and reduces bottlenecks [13].

2.8 Pokayoke and Jidoka

Pokayoke is a human mistake correcting system; it has been established that pokayoke can also act as a human mistake avoiding system. For example, when the Kanban system is implemented in a logistics warehouse, a team member could mistakenly read the number of a job card and mix up materials resulting in customer complaints. Here a barcode system could act as a pokayoke to eliminate human error [14].

Studies have shown that Jidoka is a lean tool that eliminates repeated problems by immediately stopping the production line when there is a problem. It is one of the lean tools that helps an organization to produce high quality products because it does not allow defective products to be dispatched [15].

2.9 Value Stream Mapping

The Value Stream Mapping tool was designed in the Toyota production system to evaluate value adding and non-value adding activities. The VSM tool makes it easy for the effectiveness of a system to be reviewed [16]. It has been established that the Value Stream Mapping tool is the most popular lean approach tool that is used in Industrial Engineering. It gives a systematic overview of continually improving production processes and eliminating waste [17]. Value Stream Mapping assists in illustrating and providing information on activities carried out in production and finding opportunities for enhancement that will highly benefit the entire production system. Value Stream Mapping (VSM) is a lean manufacturing tool that can be utilised to eliminate non-value adding activities in manufacturing as well as to identify the delaying processes in an industry [18].

2.10 Ishikawa

Investigating the root cause of the problem results in continuous improvement; hence Prof Kaoru Ishikawa developed a flexible problem-solving analysis tool in the 1960s [19]. Ishikawa is a fully detailed problem-solving technique that clearly indicates the deeper cause of the problem. It has also been discovered that Ishikawa includes six analysis steps, namely, defining the problem, identifying the cause, selection of the basic structure (Man, Method, Material, Machine, Measurements and Environment), development of the diagram, the process of spreading, and analysis [20]. Figure 2.4 shows an example of an Ishikawa diagram.

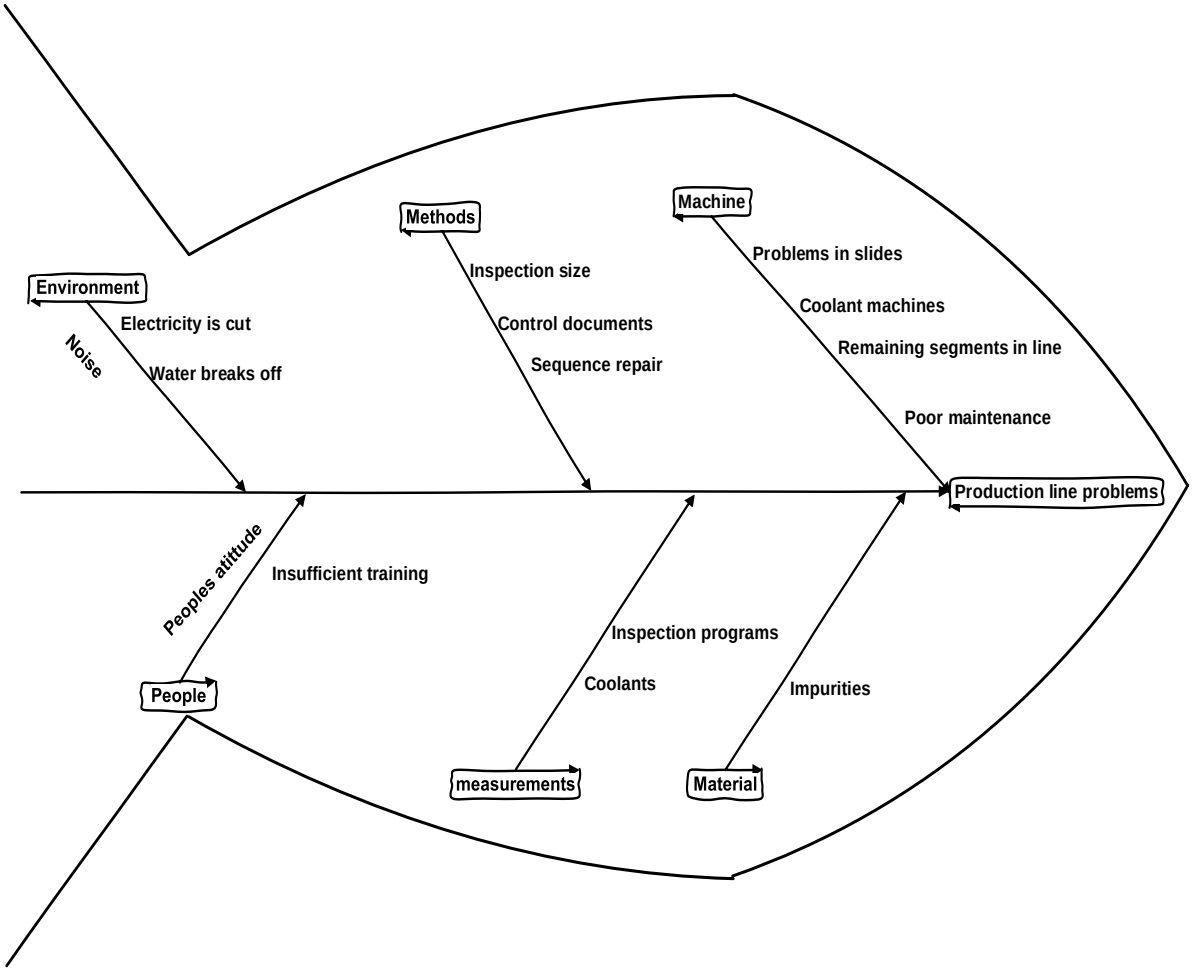


Figure 2.4: Ishikawa diagram

Source: [21]

2.11 Heijunka or Production levelling

Heijunka is a lean tool that is used to control the productivity rate over a specific period of time by maintaining the level of input distribution, that is, man, material and any other specified input. Heijuka also assists in reducing lead time. Heijunka facilitates the smooth flow of the demand planning process by eliminating interruptions to the schedule and also making sure that the supply of production input is flexible; it maintains evenness of flow of material during work in progress. Production levelling is a systematic approach that combines lean manufacturing and the Kanban system for effective use of resources [22]. Below is an example of a theoretical model of the production levelling system.

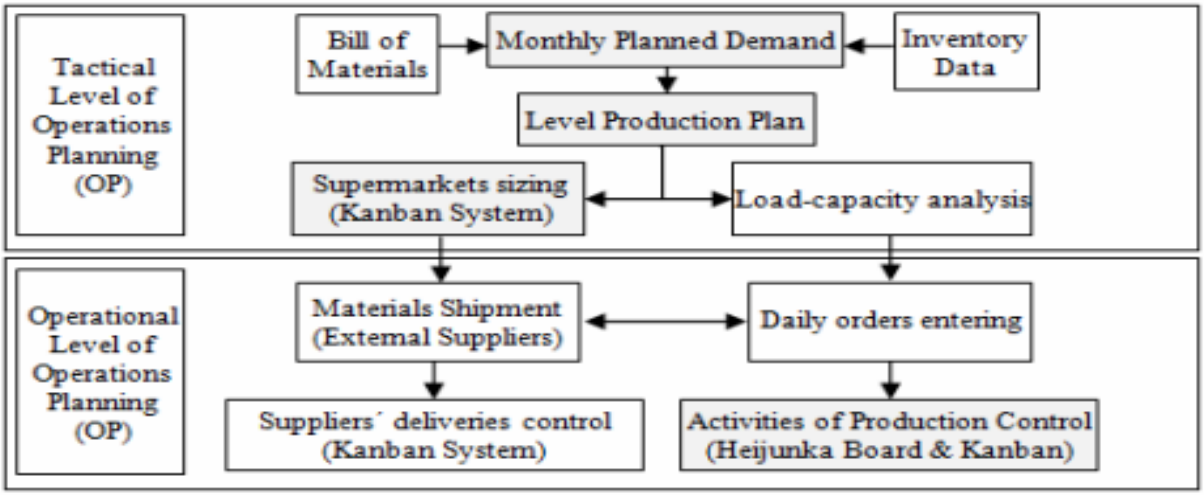


Figure 2.5: Theoretical framework of production levelling and its main activities

Source: [22]

According to the information evaluated in this chapter, it can be concluded that Lean manufacturing techniques are technical tools that optimize systems by eliminating non-value adding activities for system enhancement purposes; hence there is confirmation that lean manufacturing tools increase the rate of kaizen implementation.

2.12 Models for process enhancement projects

Models for process enhancement projects are constructed in order to solve systematic problems and to predict future risks in order to prevent those risks from re-occurring. Cherrafi, Elfezazi, Hurley, Garza-Reyes, Kumar, Anosike and Batista constructed a kaizen model to improve sustainability by assisting organizations to decrease their environmental waste in a practical and easy manner using limited resources. This study produced results culminating in the substantial improvement of resources consumption and reduced environmental impact [23].

Some organizations have adopted fully automated systems to increase their productivity rate and customer satisfaction, which triggers the need to apply computational intelligent technology. Authors who were interested in this field came together and carried out a study in order to develop a framework which was easy to use with high efficiency and good quality performance in estimating faults in different stages throughout the software improvement projects [24].

A neural network based framework, which creates models for faults estimation in advance for a software life cycle was constructed. A pattern of empirical experiments was carried out based on the input and the product taken from normal projects that resulted in drastic improvement. It was also recommended that a prediction tool be developed to suit ERP Systems, Agile and any other production system. Below is an example of how the framework was constructed [25].

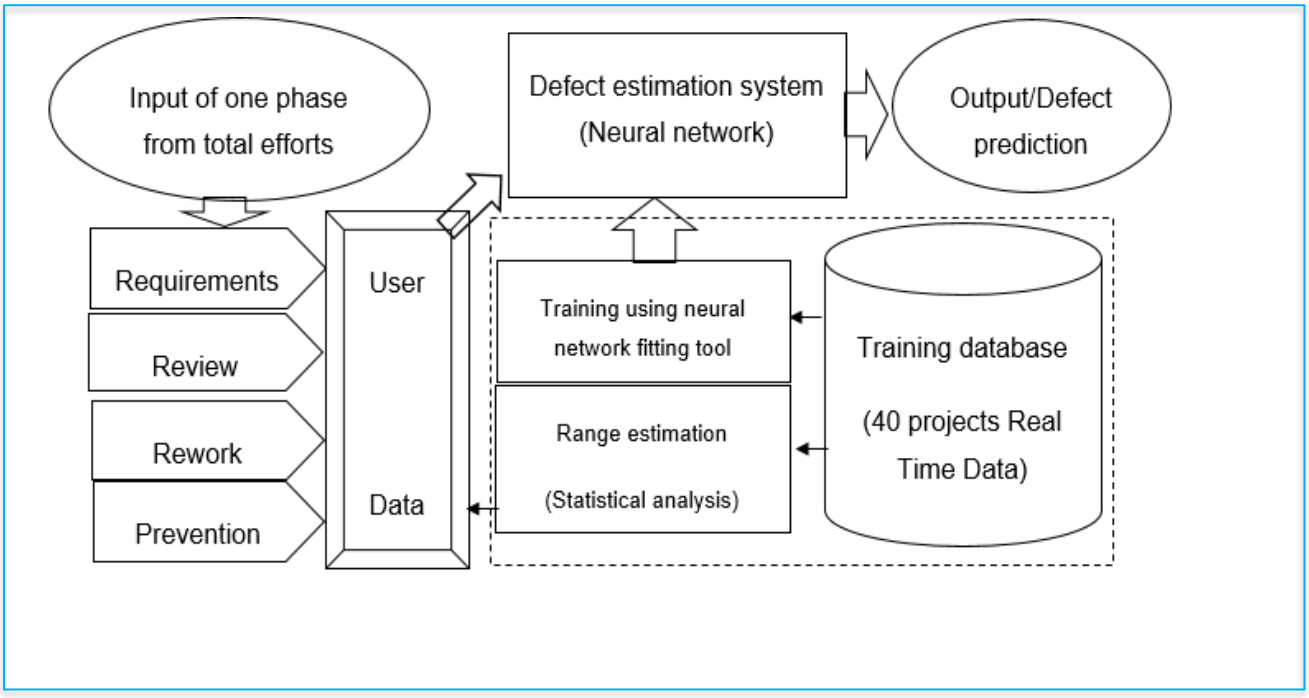


Figure 2.6: Illustration of a model framework design

Source: [25]

Models for process enhancement have been applied in a variety of sectors such as the mining sector. The mining process comprises three processes, process discovery, and non-conformance checking and process enhancement. Process discovery discovers models from event logs, conformance checking evaluates the quality of a process model, and process enhancement refines process model performance by feeding them with data obtained from the event log.

Process discovery was used to collect data to analyse results, which normally assumes that everything is correct whereas they are designed to integrate all the event log behaviour in their resulting process models as far as possible. Nevertheless, in real situations where event logs are used, noise and unrelated uncommon behaviour results in difficult process models. Hence, a novel general purpose filtering method that utilises observed conditional probabilities between sequences of activities was proposed. The proposed method was installed in both the ProM tool kit and the RapidProM framework. Results were reviewed by means of real and synthetic data, which resulted in the elimination of irrelevant behaviour and process discovery results enhancement [26].

Lean techniques serve as a tool that works together with any other system of interest; hence lean construction and building information modelling were integrated to control the project and yield the best continuous improvement project results for a big Massachusetts client. The results showed that the client needed to change internal standard practices to upgrade its supply quality. It was also found that the client needed to fully participate in continuous improvement processes to maximise profits. It was established that the building information model was not aligned with the procurement process and it was further established that an existing contract did not coincide with the building information model and lean requirements [27].

A study of opportunities for enhanced lean construction management using Internet of Things standards was carried out. Normally, productivity management is one of the complex tasks in construction sites. Here the researchers came together and integrated construction systems with lean principles, which resulted in tools like VisiLean. VisiLean is composed of four phases: production planning and control of work flow, process and product integration, visual controls and information in production, and subscription without call-back address. This tool resulted in substantial improvements to the construction site resulting in a smooth flow enterprise resource system. Below figures is an illustration of VisiLean method [28].

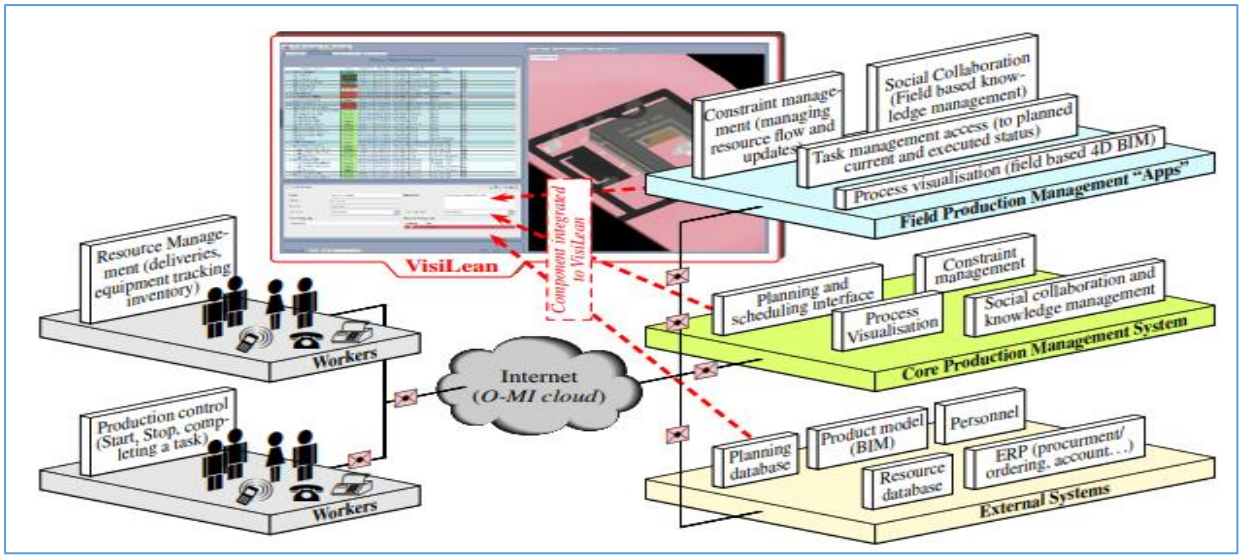


Figure 2.7: Illustration of the VisiLean method

Source: [29]

The combination of Green and Lean has been a successful methodology but for business growth it has been found that there was a need for more flexible models based on this approach.

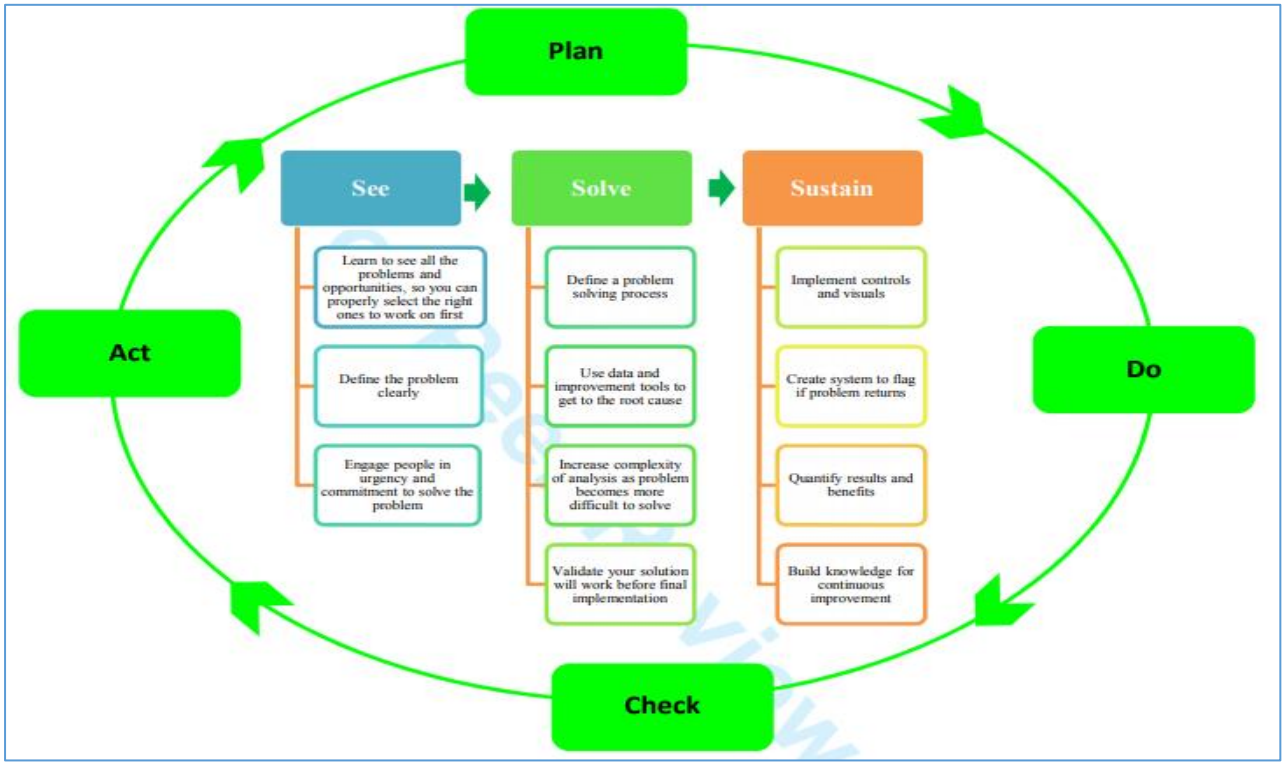


Figure 2.8: Planning cycle of the Green and Lean manufacturing approach model

Source [30]

A study was carried out using the PDA cycle plan to reduce environmental impact and a model for the combination of Green and Lean related to the kaizen Gemba approach was introduced. The implementation of the model was successful hence environmental impact was reduced. Below is an illustration of how the project was planned and implemented [30].

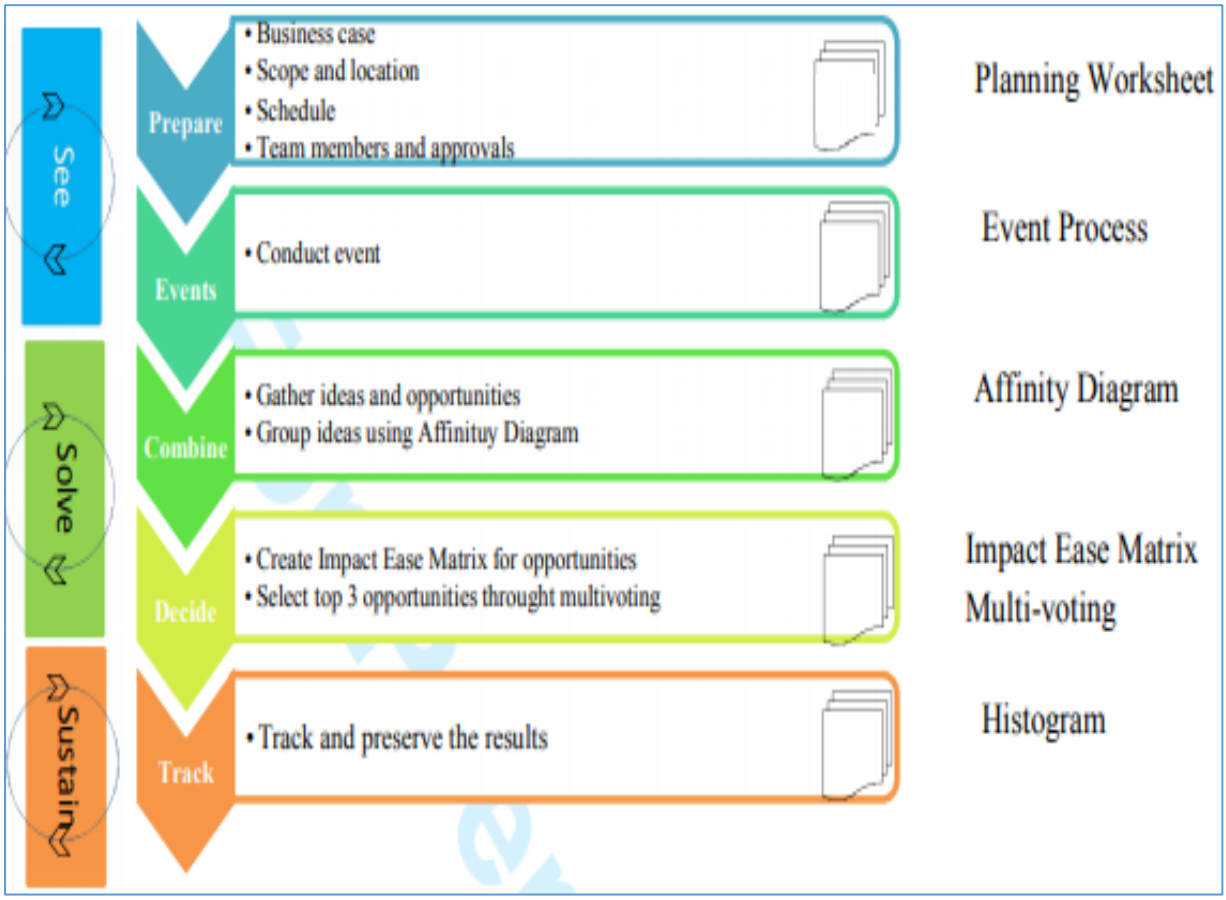


Figure 2.9: Illustration of the Green Lean model

Source [30]

A study to evaluate methods to integrate lean techniques and ISO9001:2015 was conducted; different clauses of ISO 9001 which related to lean six sigma were evaluated and linked to lean functionality. The study resulted in the complete model, which demonstrated the link between ISO9001 and lean six sigma. Such a tool can be further integrated into a software program for process enhancement for different organizations that are ISO9001:2015 certified [31]. Figure 2.10 shows an illustration of the development of Lean Six Sigma projects and how it was combined with the ISO 9001 QMS and with the clauses/sub clauses of ISO 9001.

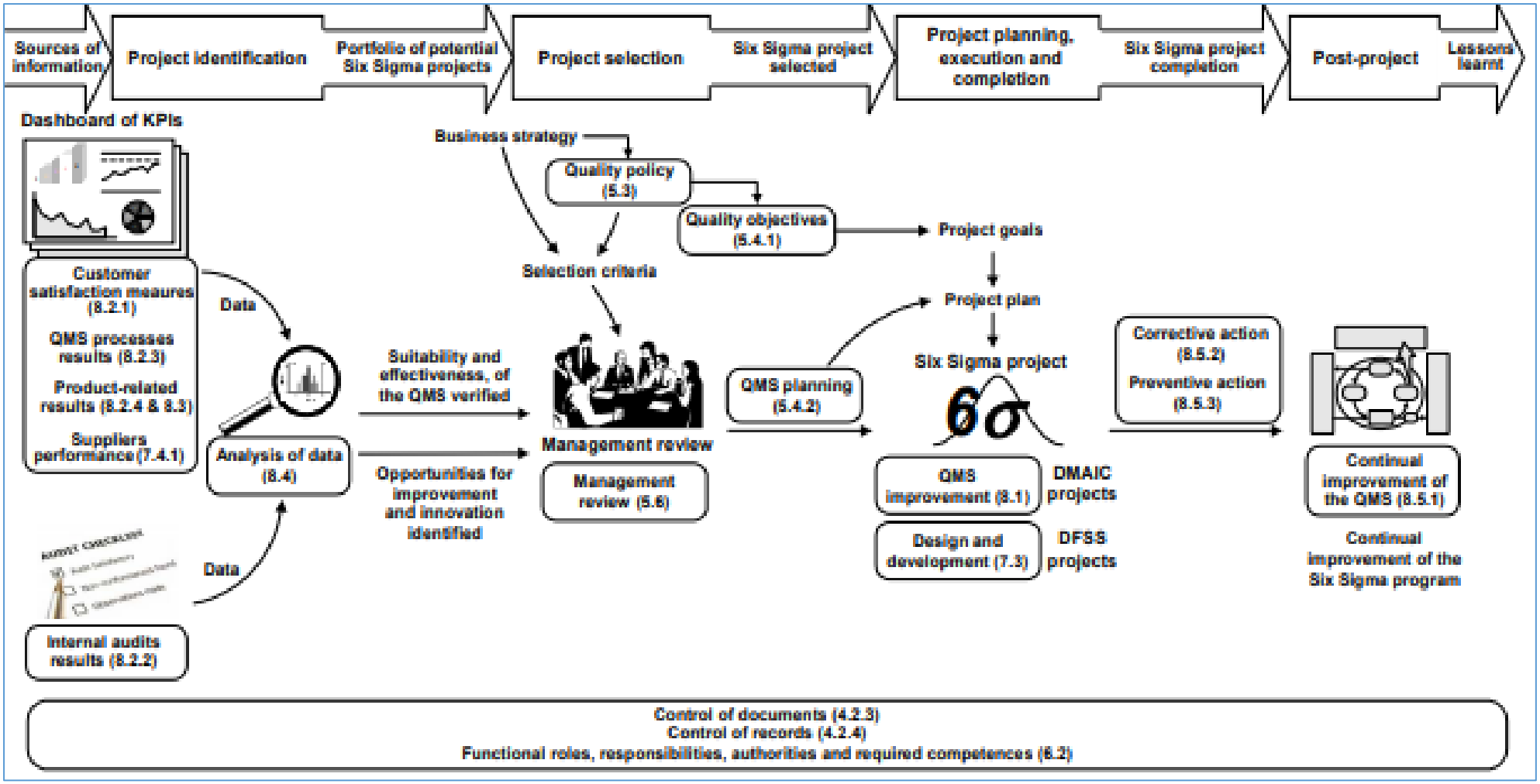


Figure 2.10: Development of Lean Six Sigma projects combined with ISO 9001 QMS

Source [31]

Lean principle and ISO 9001 standards were further evaluated and a study was conducted to demonstrate the combination of lean techniques and ISO9001:2015 quality standards. It was found that the clauses of ISO 9001:2015 were mostly related to lean six sigma functionality [32].below figure 2.11 and figure 2.12 illustrate the relationship of clauses of ISO 9001:2015 with lean six sigma

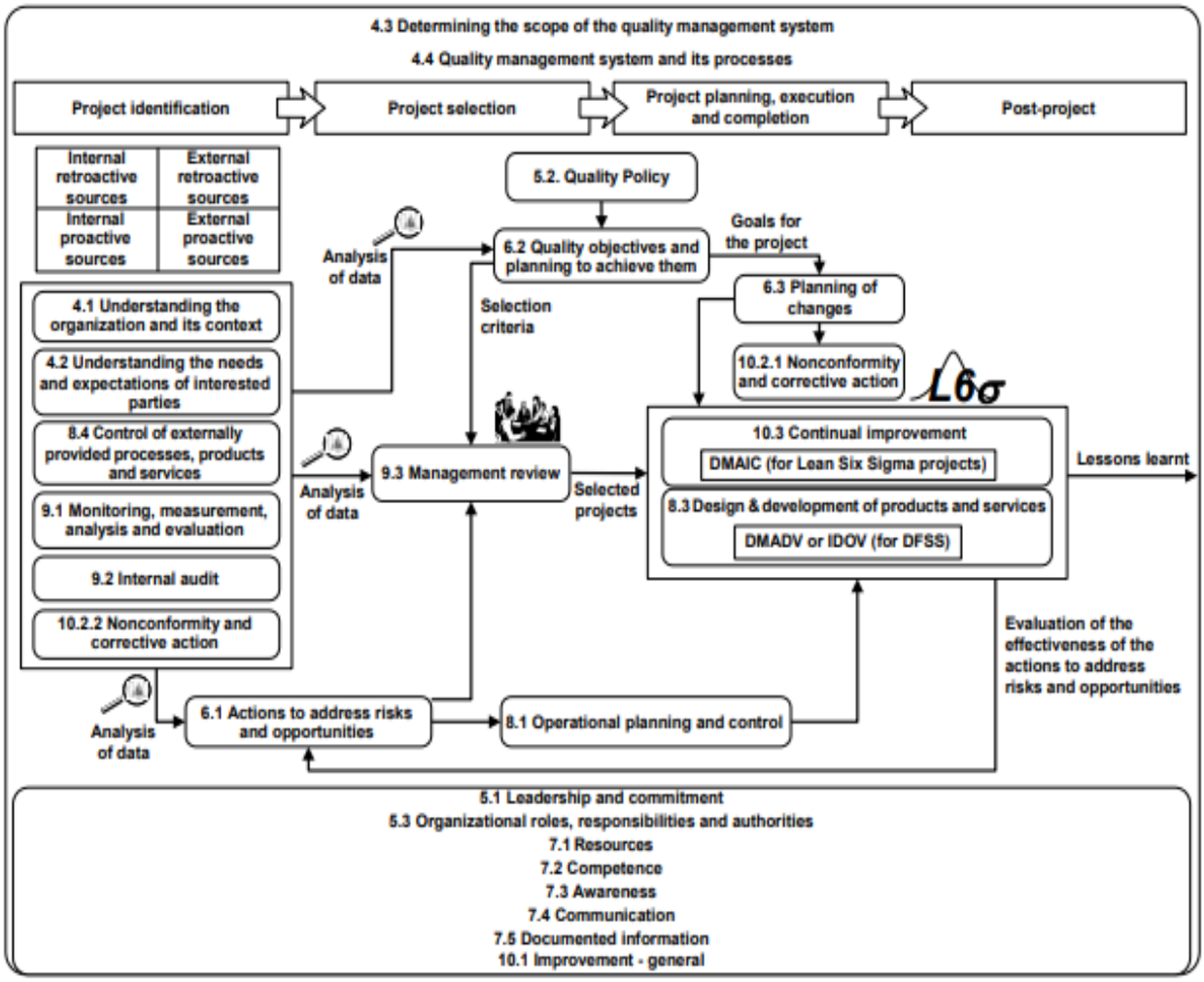
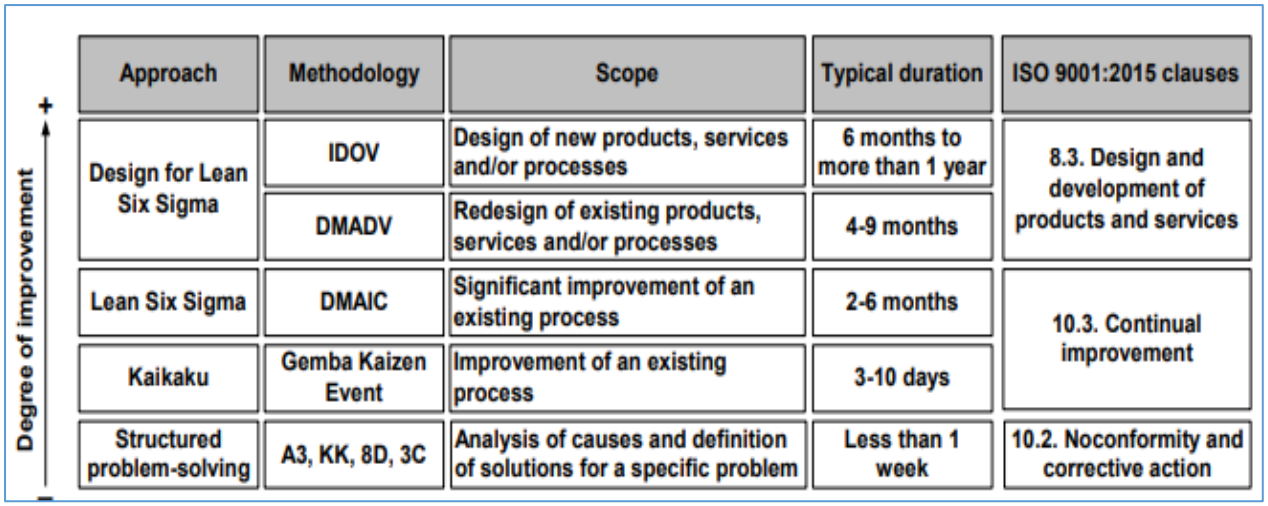


Figure 2.11: Illustration of Lean Six Sigma techniques and tools in ISO 9001:2015

Source: [32]



Approach	Methodology	Scope	Typical duration	ISO 9001:2015 clauses
Design for Lean Six Sigma	IDOV	Design of new products, services and/or processes	6 months to more than 1 year	8.3. Design and development of products and services
	DMADV	Redesign of existing products, services and/or processes	4-9 months	
Lean Six Sigma	DMAIC	Significant improvement of an existing process	2-6 months	10.3. Continual improvement
Kaikaku	Gemba Kaizen Event	Improvement of an existing process	3-10 days	
Structured problem-solving	A3, KK, 8D, 3C	Analysis of causes and definition of solutions for a specific problem	Less than 1 week	10.2. Noconformity and corrective action

Figure 2.12: Enhancement strategies, functionality and link with ISO 9001:2015

Source: [33]

2.13 Process enhancement to address non-conformances from operations

A study in an electrical motor manufacturing industry was carried out where the aim of the study was to improve the quality of the non-conformance data system. Different departments were inspected to ascertain the problems faced when non-conformances were investigated and benchmarking was done with four companies to find out about the different strategies they used for data collection. The researchers interrogated the feedback from the interviews and benchmarking and they developed a model for data collection. With a view to further improvement, reporting tools were developed and applied to create a data base system for quality complaints [34].

A study was carried out on the analysis and continuous improvement of quality systems in the production of spliced veneers. D8Methodology was applied to address non-conformances. D8Methodology is composed of 8 steps: D1 - Setting up the team, D2 - Describing the problem, D3 - Proposing temporary corrective solutions, D4 - Analysing possible causes and analysing principal causes, D5 - Proposing permanent corrective solutions, D6 - Implementation and verification of adopted corrective measures, D7 - Preventive measures and D8 - Acknowledgement of the team. The study resulted in substantial improvement in the handling of both customer and internal complaints. [35]

2.14 Lean supply chain management

Lean supply chain management is an important concept that combines the analysis of lean philosophy with supply chain management. It has been realised that the emphasis of supply chain management is on integrated planning, co-ordination and management of all logistical business processes and activities in the supply chain to achieve quality customer value at less cost to the supply chain as a whole whilst meeting the requirements of other stakeholders, such as customer care organizations and government [36].

The seven-step framework for lean supply chain management includes strategic alignment, identification of lean performance measures, implementing the Balanced Score Card (BSC) selection of lean performance measures, measuring processes, assessment of results and identification of improvement opportunities [33]. Below is a structure of the framework for Lean Supply chain management, below figure illustrate how lean strategies is applied when the problem solving technique is required and how kaizen is generated

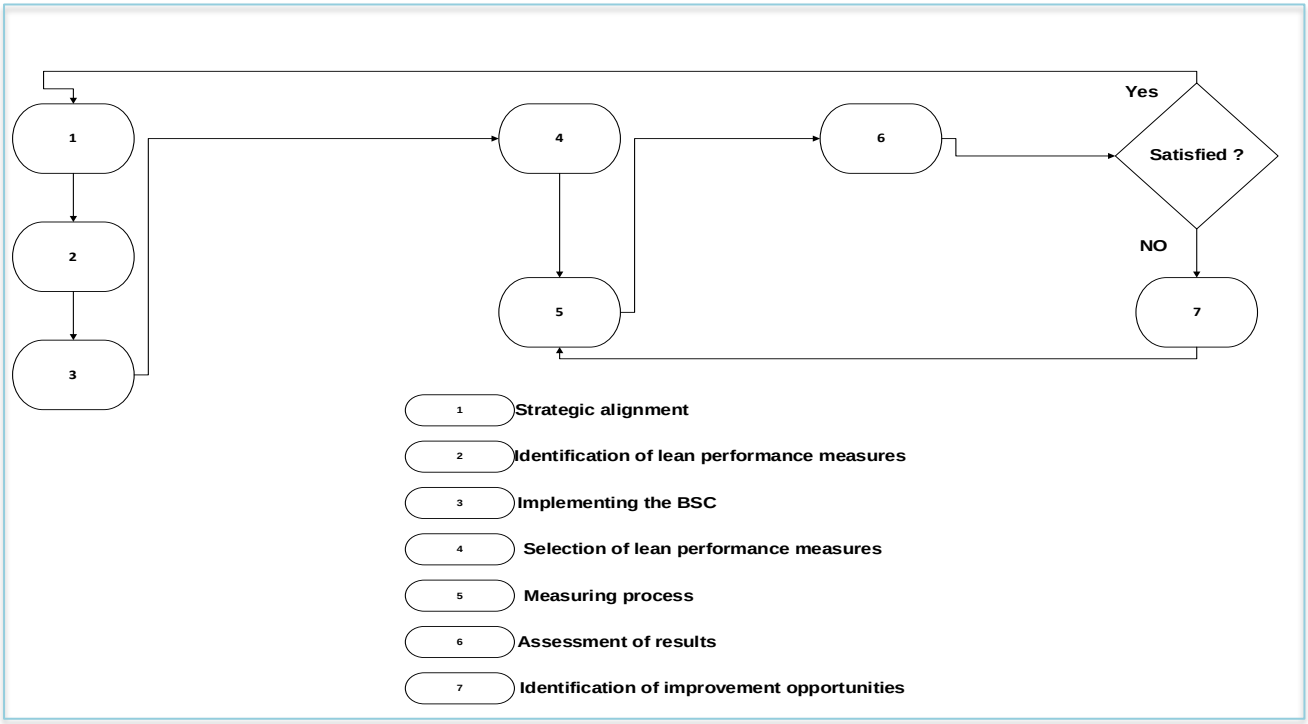


Figure 2.13: Framework for lean supply chain management

Source: [36]

As per the above information for a lean supply chain, it can be concluded that lean techniques can be applied in supply chain activities as well. The flexibility of lean tools means that lean methodology can be successfully applied in any problem statement in a case study company.

2.15 5WHYS

The 5WHYS technique is used to find different reason for the problem to happen, it give an analyst an idea of the main root cause o9f the problem, below on figure 2.14 is an illustration of how 5WHYS is applied for problem solving

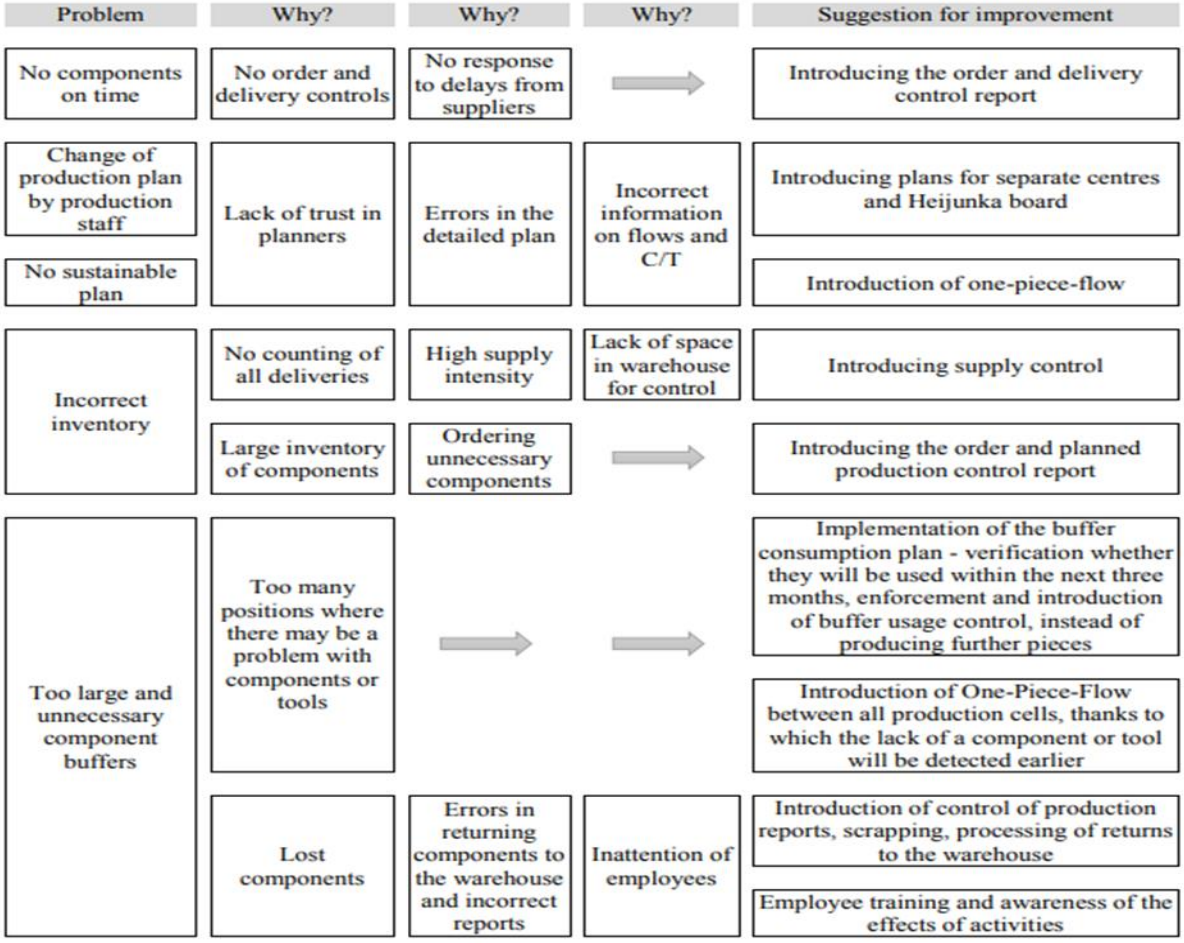


Figure 2.14: Illustration of 5Whys analysis

Source: [37]

2.16 Impact of Industry 4.0 on lean production systems

The evolution and execution of digitization and the introduction of new technologies into production systems have had a huge impact on the industry, which is called Industry 4.0. Industry 4.0 introduces a new industrial uprising based on the link between the virtual and real worlds [38]. A study conducted evaluated that Industry 4.0 utilization results in innovative technology-based, lean processes and requires infrastructural transformation and more highly skilled employee involvement [39].

Industry 4.0 is based on high technology and high technical skills. This evolution has been successfully introduced; however, there are still challenges arising that are faced by organizations. The following diagram illustrates the challenges faced in introducing Industry 4.0 into lean production systems.

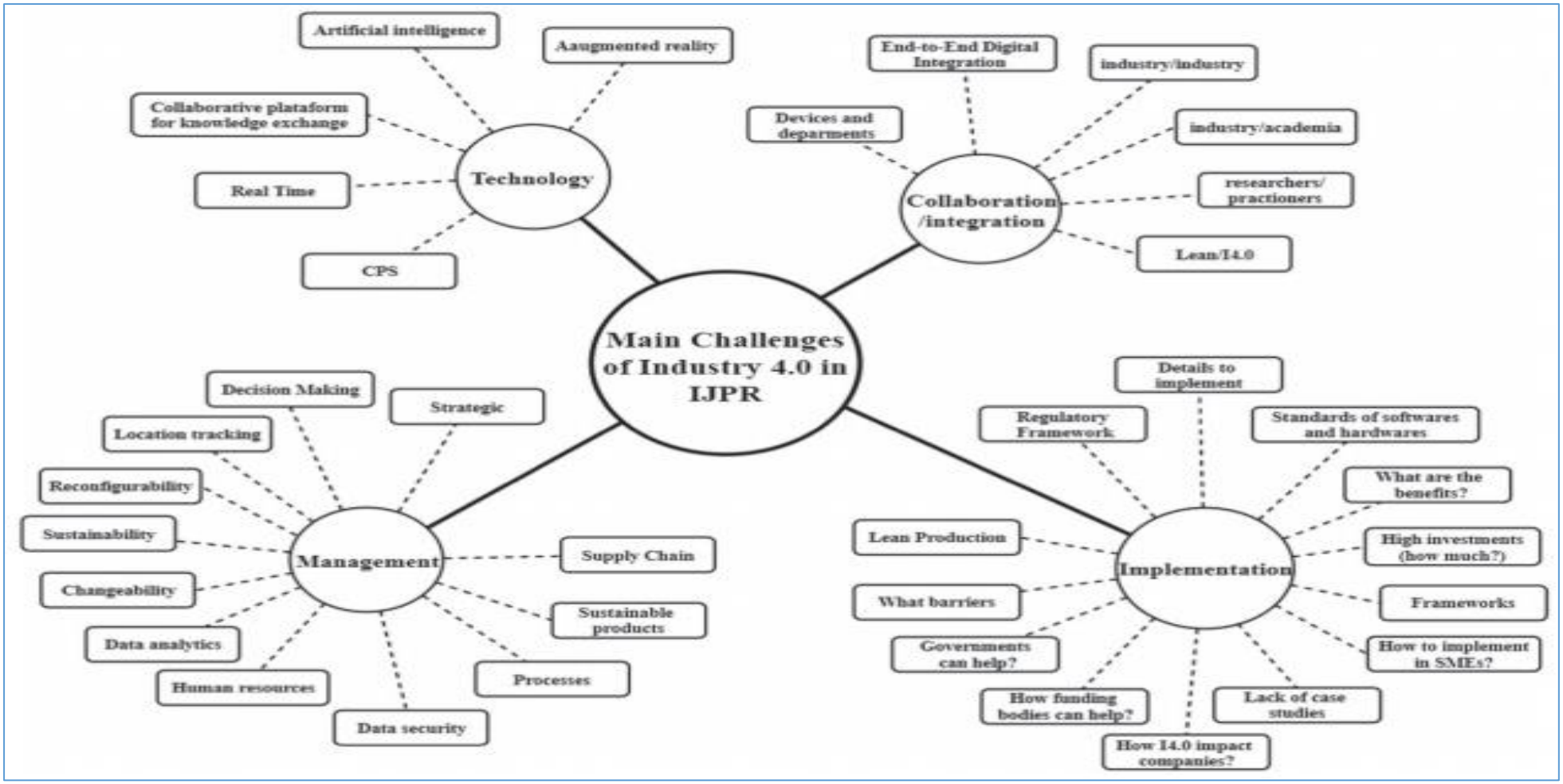


Figure 2.15: Main Challenges of Industry 4.0

Source: [39]

2.17 Adaptation of lean techniques by successful businesses

Junker carried out a study in a rapid protein production process to eliminate bottlenecks. Ishikawa, process flow diagram analysis and eight types of waste classification methodology were used. The production process was improved from 110 deliveries in ten months to 114 deliveries in eight months [40].

Lean techniques were applied in a manufacturing sheet metal stamping process; where the deburring and polishing process was the main bottleneck with a cycle time of 6,582 seconds. 5s and the pokayoke method were used to reduce the cycle time to 2,468 seconds. Process improvement was also noted in other tasks where waste was reduced from 66% to 53%, which translates to from 1086 work elements to 261 work elements [41].

Lean strategies were also evaluated in the production line of a colour industry, which was encountering unnecessary waste in the production process. Value stream mapping was used to eliminate the waste which resulted in production lead time being reduced from 8.5 days to 6 days and cycle time was reduced from 68 minutes to 37 minutes [42].

The optimum modelling tool was evaluated in respect of forecasting material properties. When mixing material for high performance concrete, there was a high consumption of material properties during the combination of chemicals and mineral ingredients. A hybrid algorithm kaizen programming simulation model with a combination of problem solving techniques was used. The results were compared against the previous model used. The kaizen programming method was found to be the optimum method because it produced a high quality mixture and the programme was faster [43].

Modelling techniques were applied in a railway transport industry where the problem was found to be lack of quality in customer service. Lean six sigma, the Leonard Berry model and an algorithm of dynamic modelling were applied to enhance the quality of customer service [44].

A study was carried out in a company manufacturing mechanical equipment. The problem identified was the long distances between the process layout which resulted in unnecessary transportation and overproduction. A time study was used to identify the product with the highest demand where improvement would be at a higher value. 5s, visual management, kanban, line balancing, Total Productive Maintenance, Overall Equipment Effective and Value stream mapping were used. It was found that the productivity rate increased [45].

A study was conducted in the automobile industry to find the best lean tool that had a significant impact in kaizen. Lean tools were listed and a sample of thirty companies was taken. Each tool was weighed and ranked accordingly. The top five tools that were found to be the most effective were: 5s and the Pareto tool led with 85%, eight step PS followed with 81%, then OEE with 80%, and elimination of waste with 75% [46].

A study was also conducted in the power distributing industry where the problem was high energy consumption due to customer demand. Value stream mapping and simulation was applied in order to eliminate waste in the process. The project was successful and the company reduced the rate of energy consumption by roughly 72.37% [47].

Lean techniques were evaluated in a carton company where the problem was found to be the length of preparation time for the process, insufficient supply of tools and equipment and inadequate planning procedure. 5s, SMED and visual management methodology were used which resulted in a substantial improvement of 47% in process preparation time which equated to €101 124 of monthly profit [48].

A study was carried out due to low efficiency in the urology department of a tertiary hospital. The PDC Cycle method was used to increase efficiency. This study resulted in substantial improvement which led to the senior practitioners' satisfaction, fewer defects in quality indicators, and meeting a risk-adjusted complication index of 0.59 and a risk-adjusted mortality rate of 0.24 within four years. A value of 0.61 was achieved with the efficiency indicator (risk-adjusted length of stay index) with a saving of 2869 stays compared with national Benchmarking (IASIST). The risk-adjusted readmissions index was the only indicator above the standard, with a value of 1.3 [49].

A study in a car multimedia company with the problem of inadequate document control procedure due to lack of adherence to quality international standards was investigated. International standards to review the procedure were applied: 5Whys, visual management, pokayoke, brainstorming and kaizen methodology were utilized to resolve the problem. A reduction from 84% to 66% in cycle time was observed [50].

A manufacturing system was evaluated using a discrete event simulation model to identify areas of improvement. After simulating the system, it was found that material was dragging the system down because of late deliveries and this was increasing the rate of idle time in the process. As a result of the intervention, delivery time improved by 50%. However, the simulation modelling was repeatedly conducted until the system was at its optimum performance [51].

A study was carried out to evaluate problems that caused inefficiencies in a business system. A Meta model system approach with an impact formula of business problem theories was used for analysis. After an overall output analysis of the selected case study company, it was found that logistics business processes had contributed to a high rate of process delays by 180 seconds which helped the business to find an area of improvement [52].

A system in a manual assembly production line was evaluated where the problem was a high rate of change-over due to a non-ergonomically friendly process layout. Value stream mapping and a line balancing tool were used to analyse the production line. Process relay-out was drafted to eliminate the distances covered to fetch the tools, which resulted in a 10% increase on the throughput rate [53]

A study was conducted into a family hotel where seven types of waste were identified with the most highlighted ones being excessive motion and transportation used in the process. 5s and a spaghetti diagram were used for analysis. These methods resulted in reduced walking distance in the process and motion was reduced by 30% [54].

A study was carried out into change management in a selected enterprise using the simulation method. After simulating different scenarios, it was found that there were some gaps needing further evaluation and repositioning in order for the company to improve its processes [56].

A system in the trimming manufacturing industry was evaluated where the process had several types of waste that were hindering the process flow. The PDCA cycle was used as well as 5s and 5Whys. The use of these lean tools resulted in a 10% reduction in the cycle time enabling them to consolidate processes and reduce the use of operators [57].

Complying with organizational standards is a currently trend since it is every organization's goal to provide good quality services or produce high quality products. Quadracci and Warn [58] defined non-conformance as any abnormal act or nature of a problem beyond operational control that occurs during work in progress, hence conformance is consistent with good performance in any system.

An investigation to reduce quality non-conformance in the textile Industry was carried out; Ishikawa and pareto analysis were applied to find the root cause. After the analysis, the major root causes were identified and resolved. Hence, the rate of kaizen implementation was accelerated [59].

2.18 Research gap

Different studies have been carried out which have resulted in considerable improvements and many positive and profitable benefits were reviewed in the above literature. However, a gap has been identified in the strategies used for operations troubleshooting in order to meet International Standards requirements. For example, one of the ISO 19001 requirements is that an organization should take appropriate corrective action without undue delay.

The above literature has shown that lean techniques and kaizen have been adopted in many businesses. Lean methodology has not been considered as a flexible tool to comply with International Standards where continuous improvement is generated, hence there is a need for more effective application of lean tools to comply with International Standards requirements and to accelerate the rate of kaizen in the case study company [60].

2.19 Conclusion

Lean techniques have been adapted in most businesses for process enhancement purposes. With reference to the above literature, one can conclude that an application of lean tools results in a more profitable organization. However, a gap has been found in that, when there are technical problems, many organizations tend to focus on applying lean techniques rather than compliance problems such as non-conformance closure to comply with international standards.

CHAPTER 3 : METHODOLOGY

3.1 Introduction

This chapter outlines the optimum methodology adopted to carry out the study. The methodology included definition, measurement, analysis, implementation and control of the proposed method in order to achieve the objectives and ethical requirements of the study.

3.2 Research design

The case study method, which qualitative in nature was adopted to carry out this study. The methodology used to create the framework for this research included DMAIC, 5Why analysis and Ishikawa. The first step was the definition of the problem statement using a cause and effect analysis diagram. The main root cause that was evaluated from the analysis, was further analysed by measuring the period of inconsistency using a graphical presentation. The next step was the proposal analysis where the semi-automated model was constructed.

3.3 Research method for objective 1

The first objective was to define the ISO standards requirements in order to evaluate the current method and identify the gap that resulted from the major finding. This objective was performed by drafting a table with all the ISO standard requirements for non-conformance systems

3.4 Research method for objective 2

The second objective was to measure the current situation, finding the root cause and demonstrating the non-conformances raised. This objective was performed by means of graphical quantification and a cause and effect diagram

3.5 Research method for objective 3

Objective number three was to construct a Microsoft excel semi-automated model for non-conformance closure. Lean six sigma tools 5Whys and the Ishikawa diagram, risks and opportunities calculations was used to design the model.

3.6 Research method for objective 4

Objective number four was to demonstrate an application of the semi-automated model on the non-conformances raised within production in the case study company. A colour coded table illustrating the different stages of the semi-automated model was developed and few defects were used to test the semi- automated model.

3.7 Research framework

The research was strategized through a specific pattern, and below is the research framework illustrating the overall scope of the study.

The first step illustrates the problem statement, which is the inconsistency of Corrective and Preventive Action System (CAPA). CAPA is the plan to address non-conformances raised, and the next step was the breakdown of ISO standard requirements. The third step was to identify the most suitable lean tools that could be used to construct a semi-automated model using DMAIC; the semi-automated model was then applied to close non-conformance. Below in Figure 3.1 is the summary of how the semi-automated model was constructed using DMAIC and Figure 3.2 is the flow diagram to demonstrate the methodology that was used to design the Microsoft excel semi-automated model.

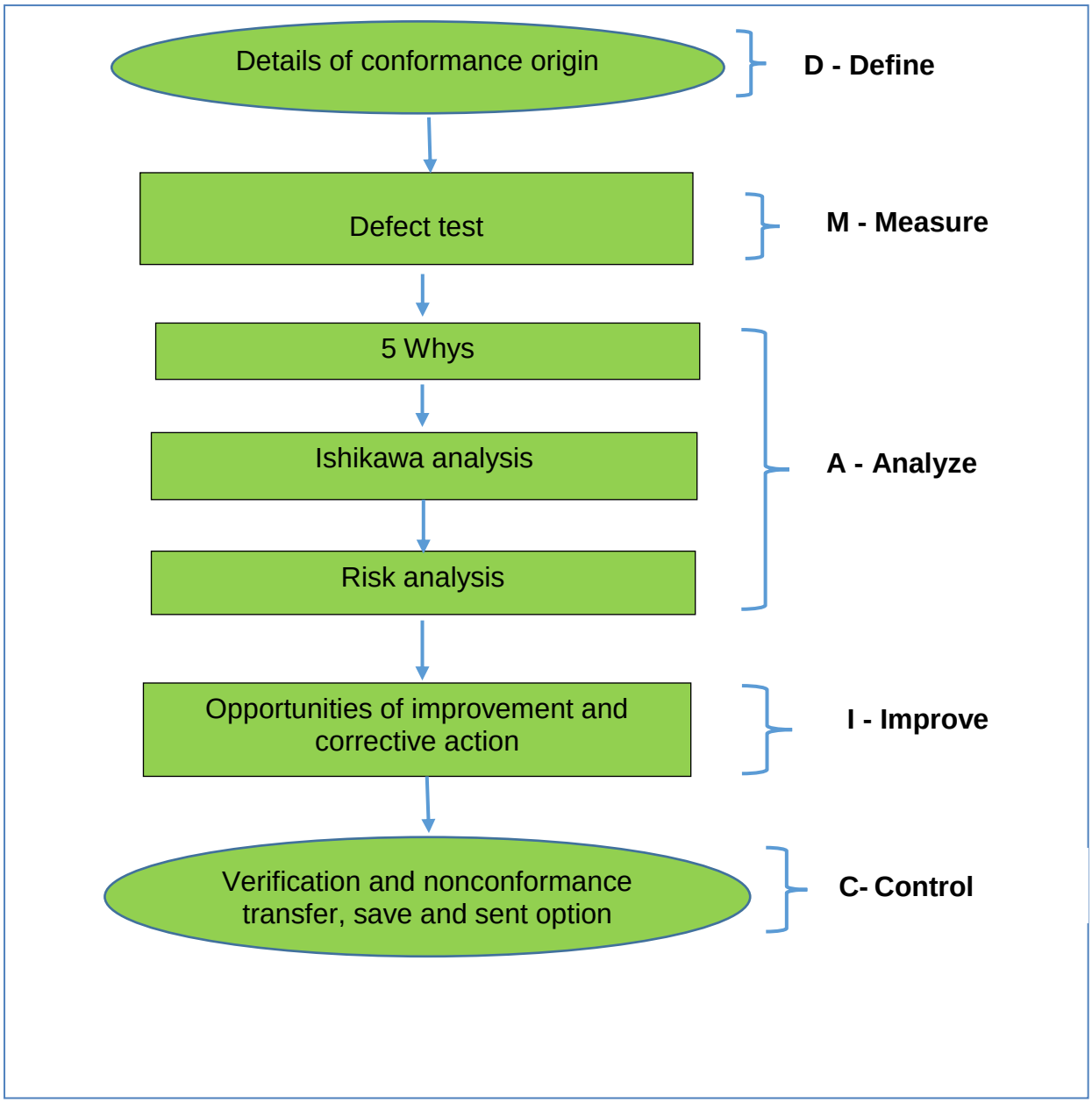


Figure 3.1: Illustration of how the model was constructed using DMAIC

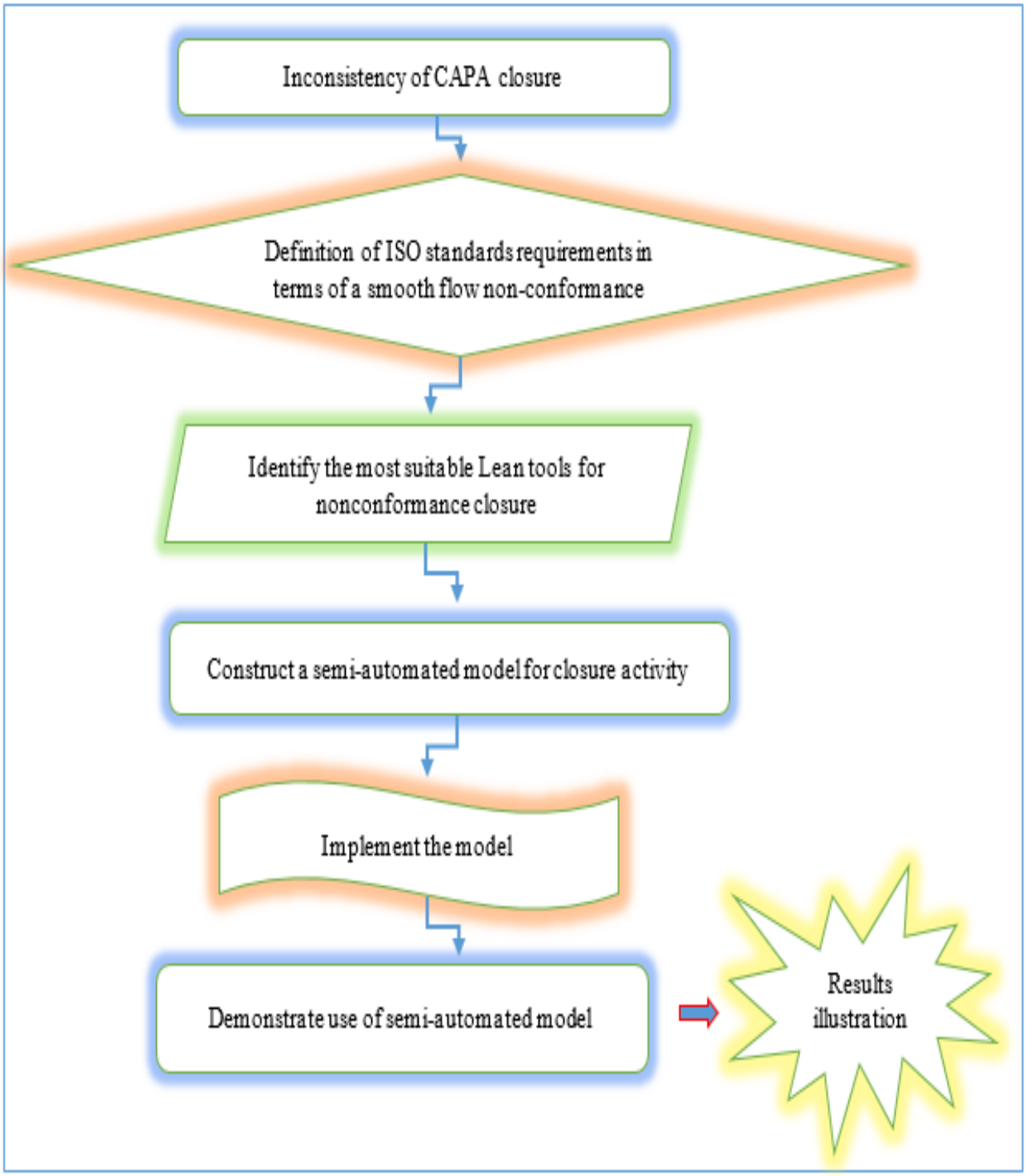


Figure 3.2: Methodology flow diagram

Source: Developed by author

3.8 Conclusion

This chapter was focused on the methodology that was adopted for the study and ethical considerations. This research was strategized through a case study format. In order to achieve the research objectives the methodology that was adopted includes DMAIC, the development of the semi-automated model using Ishikawa, 5whys, and risk and opportunities analysis. The selected methodology was based on International Standards requirements (ISO standards), it was found that lean six sigma tools aligns with quality control systems standards. This chapter focuses on the presentation of results and discussion, in the next chapter the entire scope of the work performed to address the objectives mentioned above will be outlined.

CHAPTER 4 : APPLICATION AND RESULTS

4.1 Introduction

The study was carried out in a film packaging industry based in South Africa which specialises in manufacturing plastic with thin microns called film; the main products include clear film and metalized film. The smooth flow of a non-conformance closure system generates kaizen from the defects and it also encourages the business to implement continuous improvement projects. The case study company background and objectives are addressed in this chapter, the results from the new non-conformance closure method are discussed and further improvements are outlined.

4.2 Plant overview

The case study company's process is divided into five stations namely:

- Castline:
  Castline is a process where plastic granules are melted via an extrusion process, stretched during the stretching process and simultaneously cooled. After stretching and cooling, the film is pulled automatically for winding, and in the winding process it is wound into a single jumbo roll, and then transferred by crane to the jumbo stands for curing, which means cooling and maturation for the next process.
- Slitting(cutting process):
  Slitting consists of two stages, namely, clear slitting and metallized slitting.
- Metallizing:
  Metallizing is a process where aluminium wires are heated and condense onto clear film through film pores and form a metallized surface.
- Regrind or Recycle
  The regrind or recycle process is where any recyclable scrap is recycled and converted to raw material.
- Packing
  Packing is where a finished product is packed and transferred to dispatch.
- Dispatch
  Dispatch is a process where the finished product is transferred to the customer.

Below in Figure 4.1 is an illustration of the case study company processes via a flow process chart.

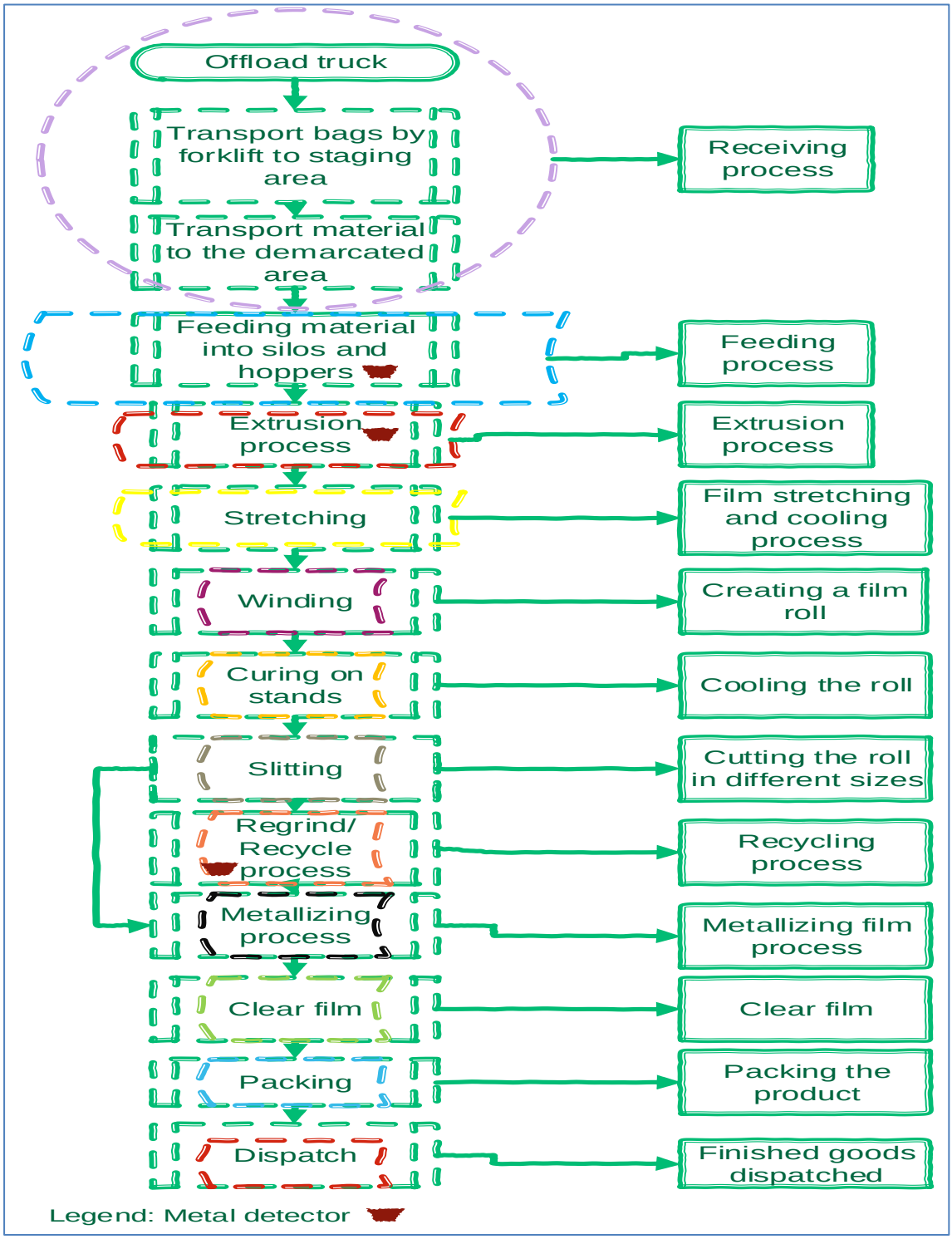


Figure 4.1: Flow process chart for the case study company

Source: Developed by author

4.3 Requirements for sustainability of TQM programme

Most profitable organizations have successfully adopted the culture of international standards requirements, which results in world class businesses. ISO standards serve as a protocol that guides the business to strive for continual improvement and enhanced safety protocols. In order to address objective number one, the table below has been constructed to clearly define the requirements for a smooth-flow non-conformance system.

Standard	Clause	Topic	Non-conformance closure requirements
ISO9001:2015	9.3.2	Management review inputs	Management review shall be planned and carried out taking into consideration performance and effectiveness of quality management systems including the following trends: ❖ Determining whether similar non-conformities exist or could potentially occur ❖ Monitoring the effectiveness of actions taken to address risks and opportunities ❖ Creating opportunities for improvement ❖ Monitoring and measurement of results
ISO 45000:2018	9.3	Management review	Top management shall review the organization's Occupational Health and Safety management system at planned intervals to ensure its continued suitability, adequacy and effectiveness. The management review shall include consideration of: ❖ Information on the Occupational Health and Safety performance, including trends, incidents, non-conformities, corrective action and continual improvement.
	10.2	Incident non-conformity and corrective action	The organization shall establish, implement and maintain a process including reporting, investigating and taking action to determine and to manage incidents and non-conformities.
ISO 45000;2018	10.2	Incident non-conformity and corrective action	The organization shall retain documented information as evidence of : ❖ The nature of the incidents or non-conformities and any subsequent actions taken. ❖ The results of any action and corrective action including their effectiveness.

Table 4.1: Illustration of requirements of non-conformance closure

Source: [60]

4.4 Evaluation of closure inconsistency of non-conformances

4.4.1 Non-conformance current operating procedure

The current method of raising a defect that has occurred in a production line is performed by a quality controller. Once the quality controller has identified a defect in the product they raise a non-conformance for that specific area and manually record it in a hard cover book for closure. Below is the flow process chart for the current procedure of raising defects and types of defects that are normally raised within the financial year.

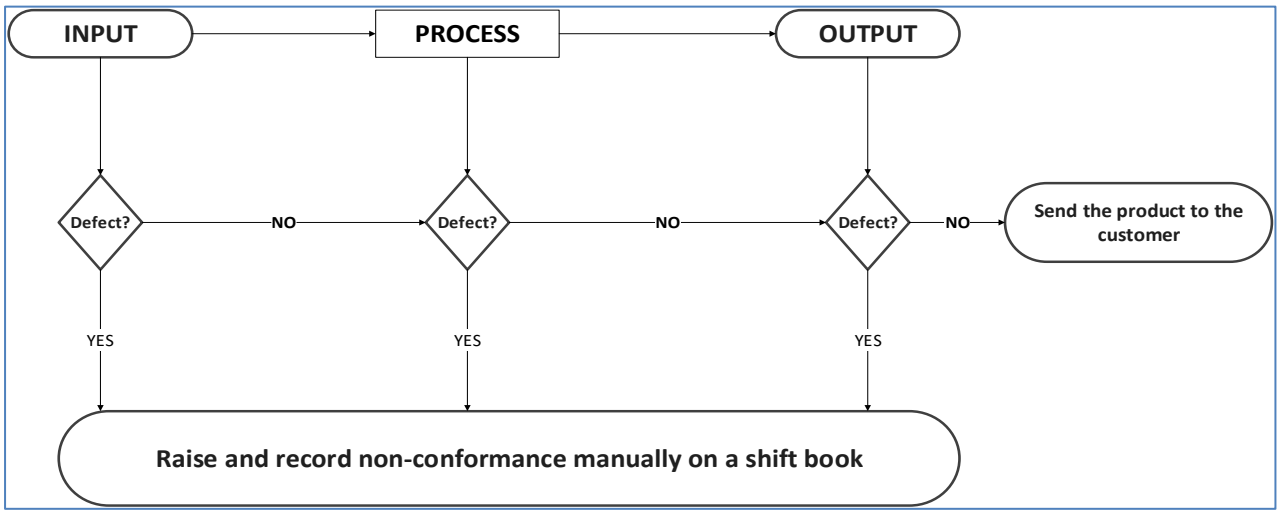


Figure 4.2: Illustration of current method for non-conformance closure

Source: Developed by author

4.4.2 Different types of quality defects raised

The inconsistency of the non-conformance closure system results from various factors; understanding and quantifying quality defects assists the operator to study the nature of the production failure and to implement proper standards to decide how a defect becomes a non-conformance. Below in figure 4.3 the different types of quality defects for the case study company's previous financial year are listed.

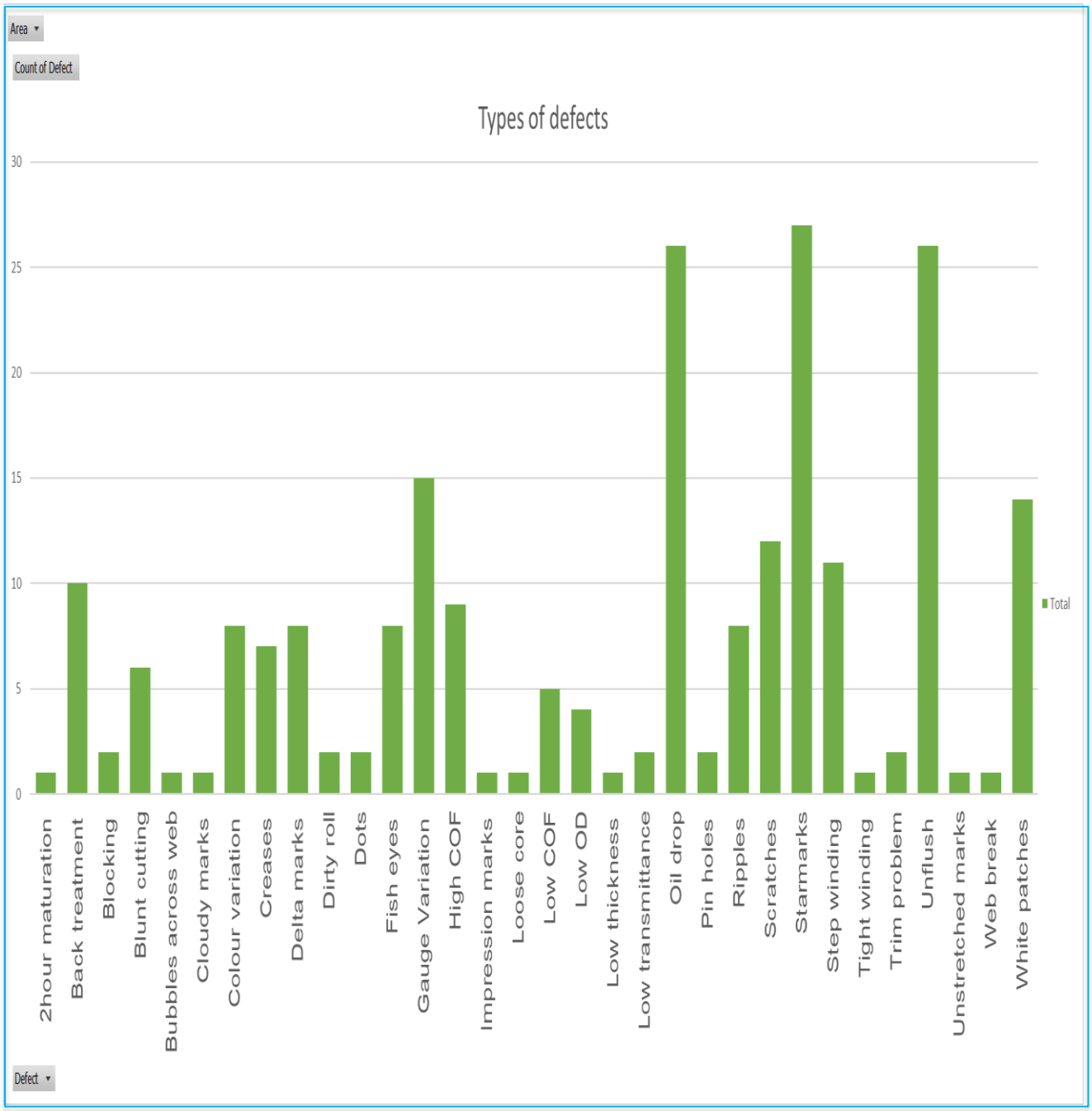


Figure 4.3: Illustration of different defects raised per financial year

Source: Developed by author

4.5 Quality of non-conformance closure procedure vs international standards

This section focuses on the evaluation of the quality of non-conformance closure procedure in terms of the adherence to international standards.

4.5.1 Measure (inconsistency of non-conformance closure)

The root cause of the inconsistency around the closure of non-conformance has been evaluated using a cause and effect diagram. It was found that the main cause was inadequate procedure due to the unstandardized closure system and the closure process was manually recorded. The operator has to record the defect in the hard-cover shift book to raise the non-conformance, which process is not accurate enough; hence this problem has resulted in a major finding. According to the analysis below it was found that the specific cause of the inconsistency was inadequate procedure.

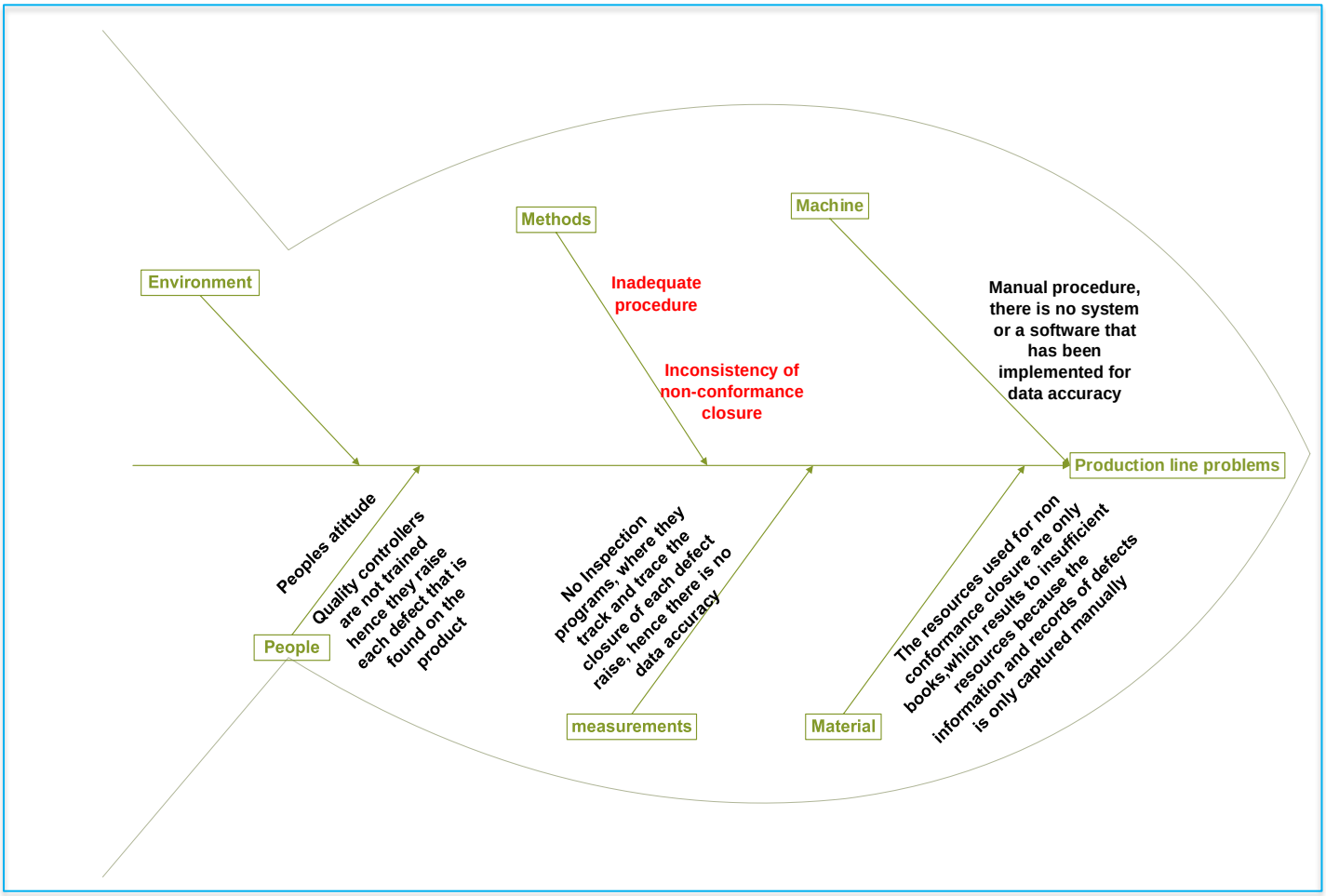


Figure 4.4: Illustration of the problem statement

4.5.2 Measurement of the current situation

In the case study company, defects that are raised as non-conformances are recorded in a shift book, and a study of occurrences per financial year has been conducted. However, it has been found that some defects have less than zero chance of occurring monthly, as they happen once a week. Below is an illustration of occurrences given as percentages. According to the following analysis, it is clear that there are no limits to raising a non-conformance. The procedure of raising a non-conformance is not clearly defined and standardized; hence these non-conformances were still open.

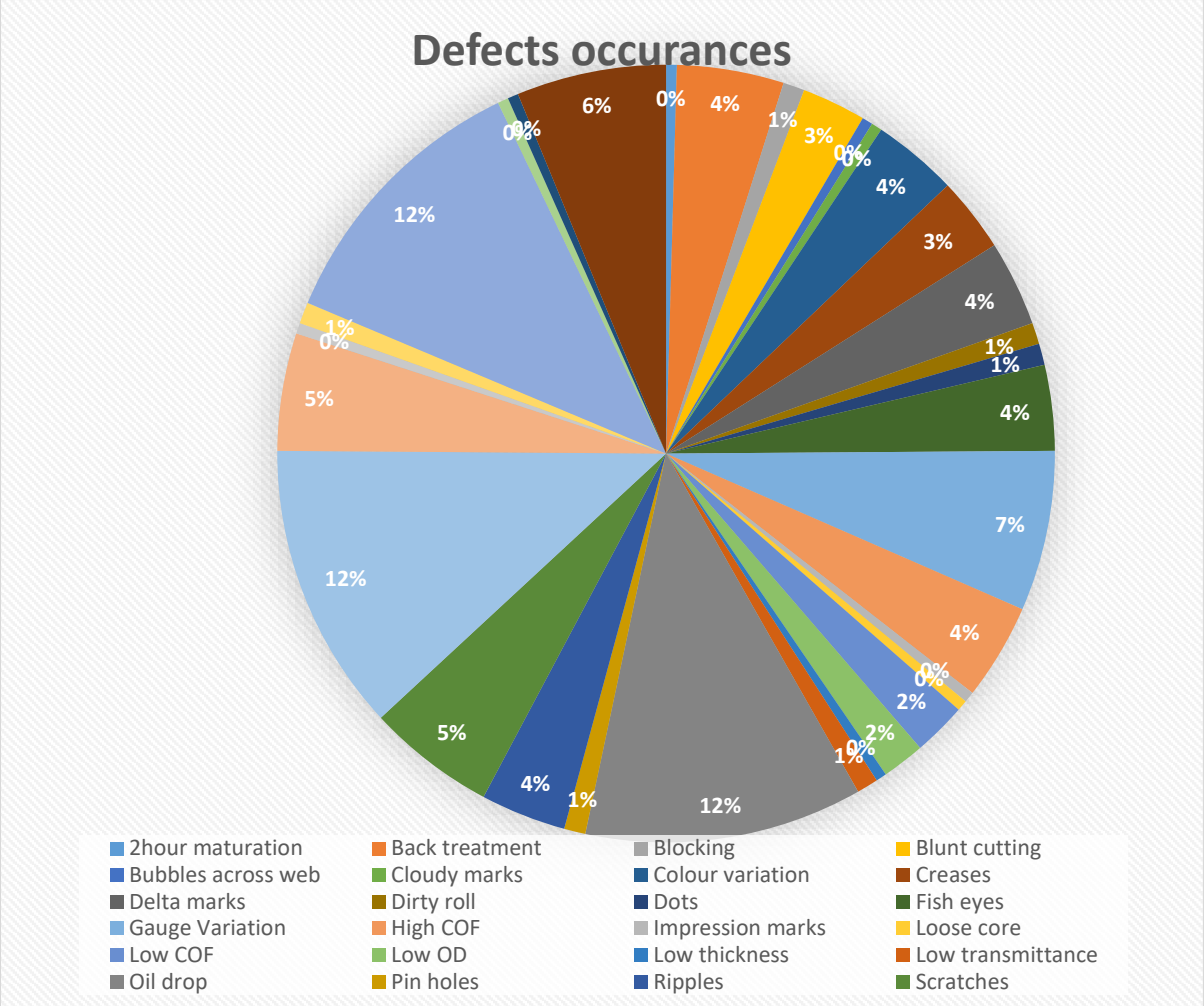


Figure 4.5: Illustration of non-conformances frequency

4.6 Development of a semi-automated model for process enhancement projects

The semi-automated model has been constructed and implemented in this chapter. One of the non-conformances raised will be illustrated using the non-conformance model. The problem statement was oil drops observed on the film. Below is the screenshot showing how the problem was resolved. The semi-automated model was divided into six sections and a colour coding table was created to give full details of each section of the model.

4.6.1 Stage 1: Details of non-conformance origin

Section one is where one records the details of the non-conformance; the problem statement was oil drops observed on the film. Below is the colour coded table illustrating each section in the model where each section has been colour coded and explained accordingly. In the table, the input data is the information recorded and code is the colour used to categorize the information. The oil drop problem originated from the cast line working station in the cooling zone process.

After the extrusion process, the film is cooled while it is automatically stretched in a vertical closed cooling chamber. The cooling chamber works with chains that constantly pull the film for cooling inside the chamber; there are fans accelerating the cooling process. When the chamber is not adequately cleaned, it accumulates oil stains from the chain, which evaporate and leave condensate on the product. Below is the cooling chamber with tiny oil droplets formed when the chamber is not adequately cleaned.

Figure 4.6: Photo illustrating oil droplets that result in product defect

Input details	Colour code	Description
Non-conformance record number		A unique number for the raised nonconformance
Date		The date where nonconformance was raised
Operator name		The name of the person operating the machine
Origin of non-conformance		The details of nonconformance origin
Reel numbers		Each reel where the nonconformance is raised has a specific number for easy traceability
Item code		Each product has a unique item code
Person who found the non-conformance		Details of the quality inspector
Quantity rejected		any due to the nonconformance raised
Issued to(The person to receive non-conformance)		The person or department to handle the nonconformance
Design of the product(Clear, white or metallised film)		Film type or product type
Machine		The name of the machine where the nonconformance originated
Classification of defect in terms of departments or area		Classification of the defect issue whether it is a safety issue or engineering issue and specification if other
Specification of root cause analysis if required		Indication whether root cause analysis is required or not
Full details of non-conformance		Full details of nonconformance raised
Test validation of the product from quality lab		Specification of the test that was perfomed on the product

Table 4.2: Semi-automated model colour coding

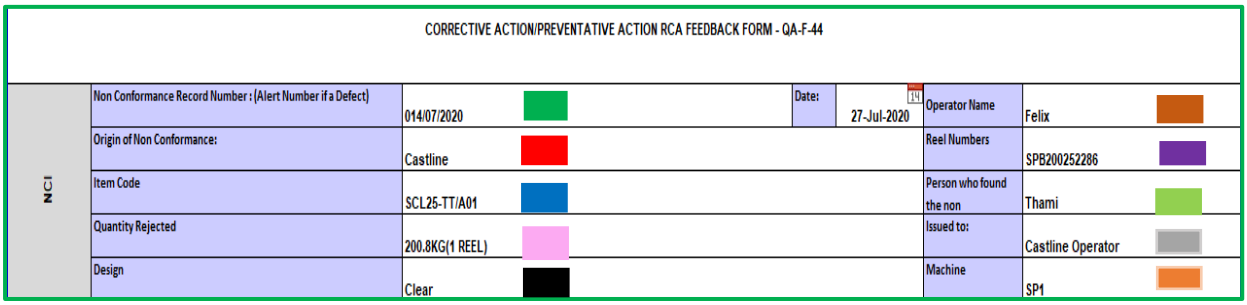


Figure 4.7: Illustration of non-conformance details

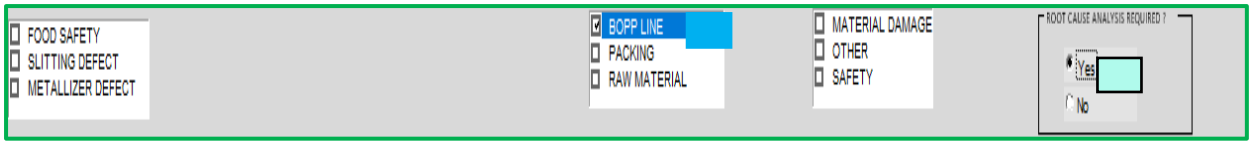


Figure 4.8: Non-conformance origin and specification whether analysis is required

If no Root Cause analysis is required, please give a reason)	
Details of Non-Conformance	
Oil drop observed on the Jumbo roll 650mm from drive side.	
Validity of Non-Conformance complaint. If the Non-conformance is not visible (i.e. Strength of product) list the test/s conducted to determine validity thereof. (TO BE COMPLETED BY THE INVESTIGATOR)	
Test Done	Visual Inspection

Figure 4.9: Illustration of details of non-conformance and validation tests

4.6.2 Stage 2 - 5 Why analysis

Stage 2 is based on the 5 Whys analysis to investigate the reason for the problem. All the possible reasons of the 5 Whys analysis were identified and it was found that the main reason for the oil droplets was inadequate cleaning procedure. Figure 4.10 illustrates a screenshot for the 5 Whys analysis on the Microsoft Excel platform.

Validity Of Non-Conformance complaint. If the Non-conformance is not visible (i.e. Strength of product) list the test/s conducted to determine validity thereof. (TO BE COMPLETED BY THE INVESTIGATOR)	
Test Done	Visual Inspection
Root Cause Analysis - (TO BE COMPLETED BY THE INVESTIGATOR)	
Why? 1	
Oil drop results from the cooling zone	
Why? 2	
Oil condensates and forms small droplets during cooling process	
Why? 3	
The cleaning of cooling zone is done when there is a line stoppage	
Why? 4	
Why? 5	

Figure 4.10: Illustration of root cause analysis

4.6.3 Stage 3: Ishikawa analysis

Stage 3 is the Ishikawa analysis, where the main reason derived from the 5Whys analysis is classified into categories of Ishikawa to generate solutions for continuous improvement. Figure 4.11 illustrates the selection of Ishikawa elements whereby the analyst selects the categories from a dropdown menu.

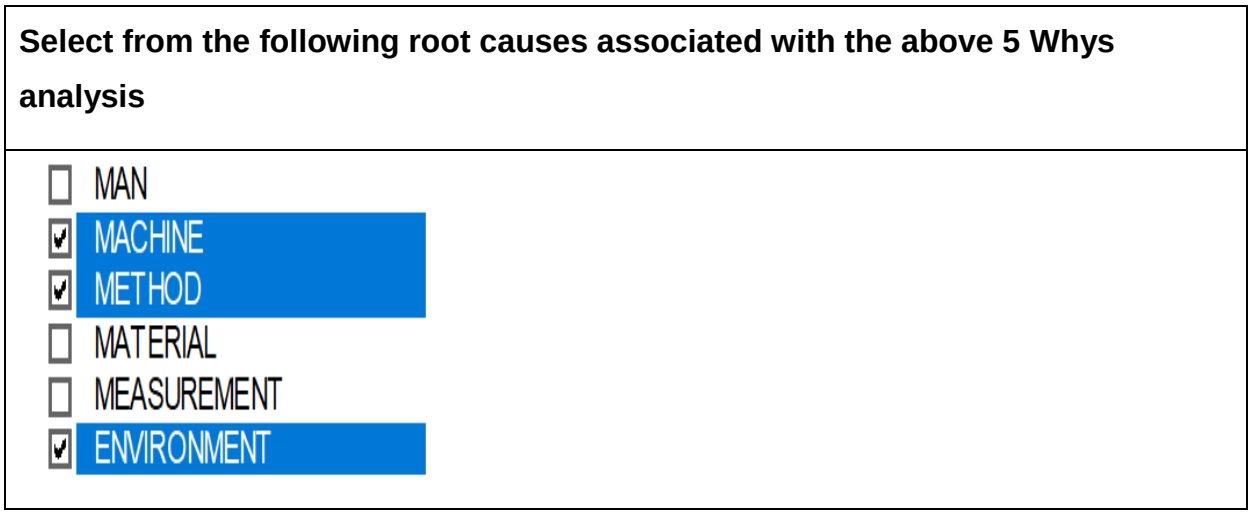


Figure 4.11: Illustration of Ishikawa analysis

4.6.4 Stage 4: Risk analysis

Stage 4 is based on the risk analysis of the problem. The assessment of the level of risk that characterize the defects in terms of how it affects the business in terms of product quality and quality of service delivery was carried out. The oil drops were likely to happen on the production line; the consequences were minor because once this defect was raised the solution is known. Figure 4.12, 4.13 and 4.14 illustrate the problem ratings.

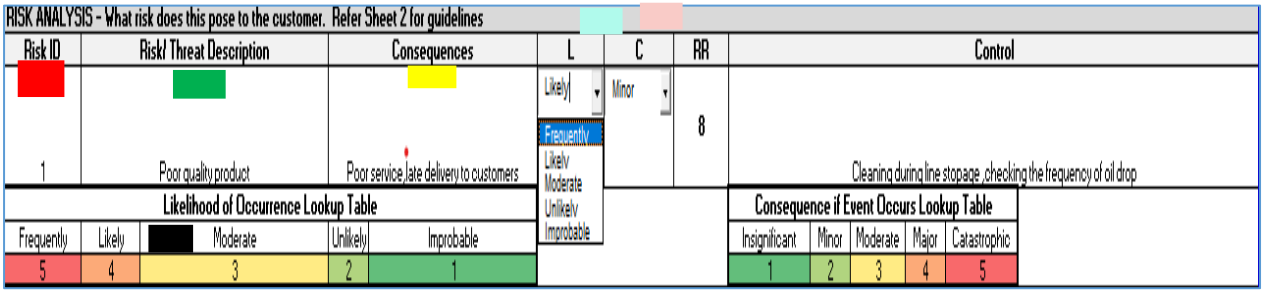


Figure 4.12: Illustration of risks analysis rating

Input details	Colour code	Description
Risk Identity(How many risks are found related to the defects)		Risk identity option,is for the total conts of risks that has risen from the nonconformance raised
Risk or the treat description		Risk or treat description,requires the user to specify what risks and treat could potentially happened due to the nonconformance that has occurred
Consequences of the defects towards the customer		Consequences of defects towards the customer,is the effect of the nonconformance that has occurred interms of customer satisfaction
Likely hood of occurrences refers to the frequency of the defect		Likely hood of occurences,is an evaluation of how likely the problem occur or the frequency occurance
Consequence if the event occurs refers to the rate of the damage if the event occurs		Consequence if the event occurs is the rating related to the measurement of damage that has been done.For an example,the whole batch has to be rejected?
Likely hood dropdown list with automated values		Likely hooddropdown list is for the user to select likely hood option according to the defect nature
Consequences of the event dropdown list with automated values		is for the user to select consequence option according to the defect nature
Rating Rate (RR),Is the product of likely hood of a defect occurrence and the consequence if the event occurs		Rating rate is calculated automatically,it is generated from the product of Likely hood and Consequencies
Control, refers to the standards implemented to minimize risks of the defect to happen again		Control refers to nthe principles in place to prevent the event to happen again

Table 4.3: Semi-automated model illustration

RISK ANALYSIS - What risk does this pose to the customer?										
Risk ID	**Risk/ Threat Description**	**Consequences**	**L**	**C**	**RR**	**Control**				
1	Oil drop can result in high defect rate	Increase of defect rate results in poor quality hence customers will not trust our product quality	Likely	Insignificant	4	Cleaning schedule has been created and the frequency has been increased				
Likelihood of Occurrence Lookup Table						**Consequence if Event Occurs Lookup Table**				
Frequently	Likely	Moderate	Unlikely	Improbable		Insignificant	Minor	Moderate	Major	Catastrophic
5	4	3	2	1		1	2	3	4	5

Figure 4.13: Illustration of risks analysis calculations

4.6.5 Stage 5 - Opportunities of improvement and correction

The last two slots of the model are opportunities for improvement of the defect, the action plan for improvement, implementation and the responsible person. The second slot is where an analyst logs corrective action that should be taken when a problem is detected. Figure 13 illustrates opportunities for improvements to and corrective action in respect of the non-conformance raised.

Opportunities	Action Plan	Due Date	Responsible Person
Improvement on the cleaning procedure	Cleaning schedule has been drafted	**13/03/2020**	Shift section in charge
Correction (TO BE COMPLETED BY INVESTIGATOR) - What immediate corrective action was taken to solve the problem?			
The roll was reworked and the cooling zone was cleaned.			

Figure 4.14: Illustration of risks analysis calculations

4.6.6 Stage 6: Communication

Stage 6 is communication whereby the analyst saves and sends the completed form. The form is sent automatically to the Total Quality management co-ordinator as illustrated in Figure 4.15. Figure 4.15 shows an illustration of the validation and transfer of the complete non-conformance investigation report.

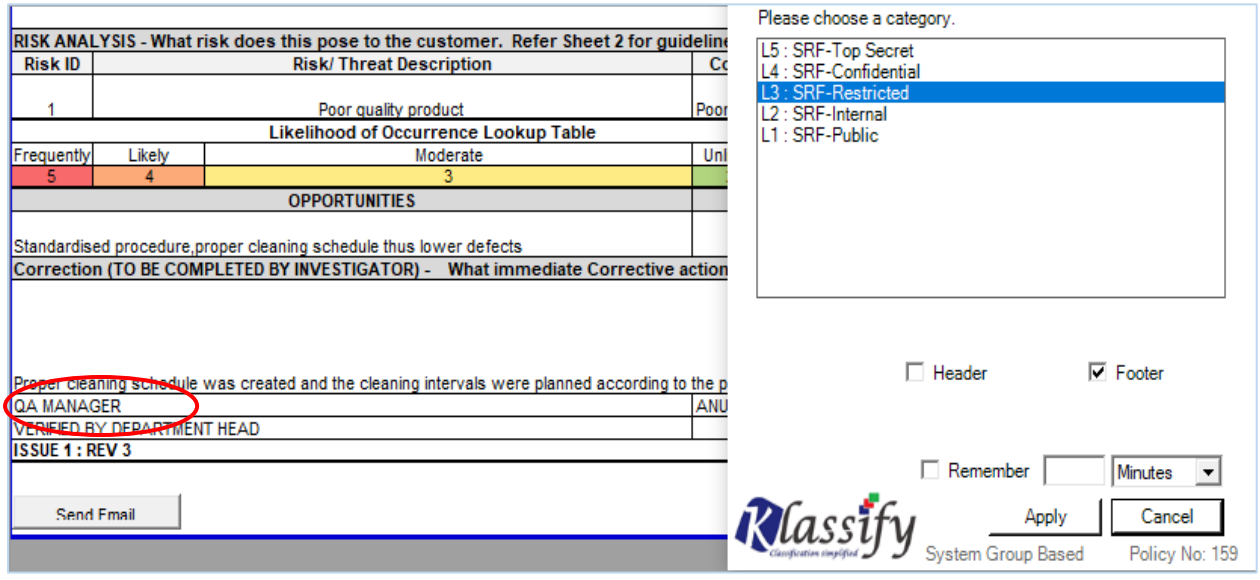


Figure 4.15: Validation and transfer of non-conformance investigation report

4.7 Sample defect solutions from using the semi-automated model

4.7.1 Observation of DIE line on the product

Below is one of the defects that were resolved via the semi-automated model. Figures 4.16 to 4.20 represent a die-line non-conformance that was observed in the product. Two rolls were rejected due to dust on the machine; for corrective action, the rolls were reworked and sold as B grade.

4.7.1.1 Section 1 - Details of a non-conformance origin for DIE line

Figure 4.16 illustrates the details of a non-conformance origin, including the defect alert number, details of the quality controller and the operator on the shift, machine name, quantity rejected as well as the area where the non-conformance occurred.

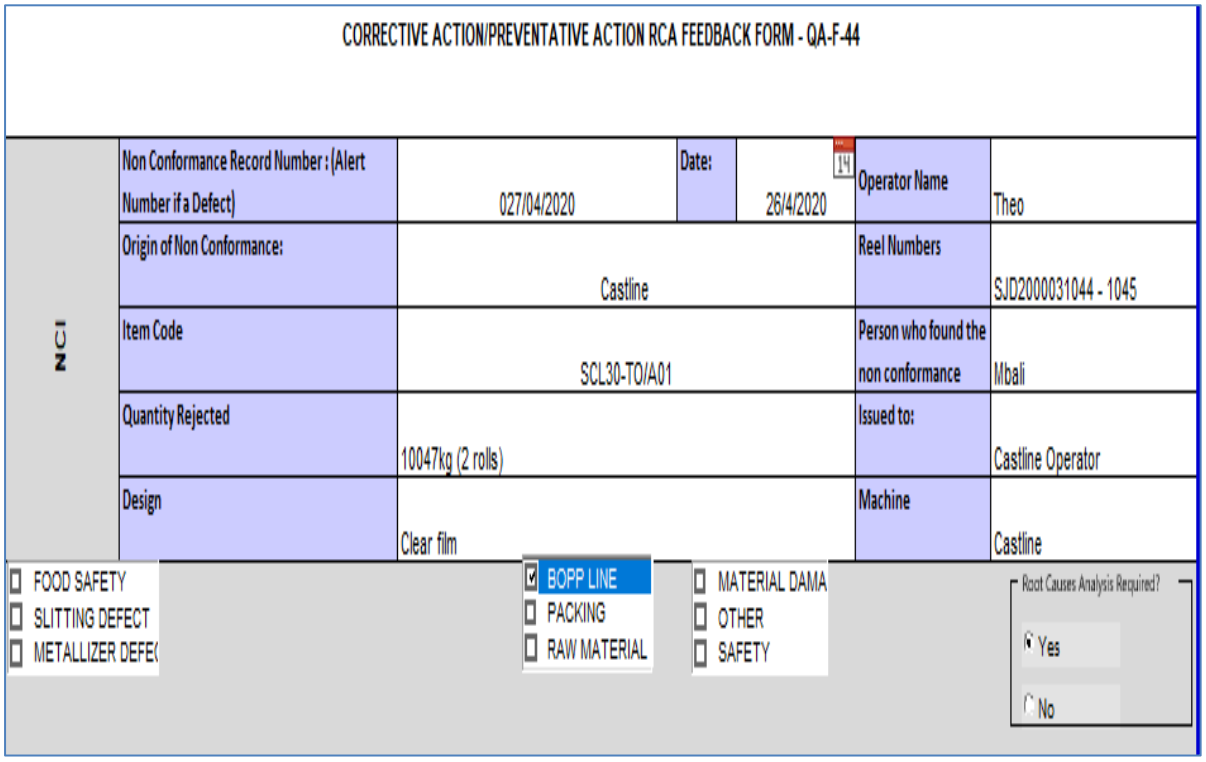
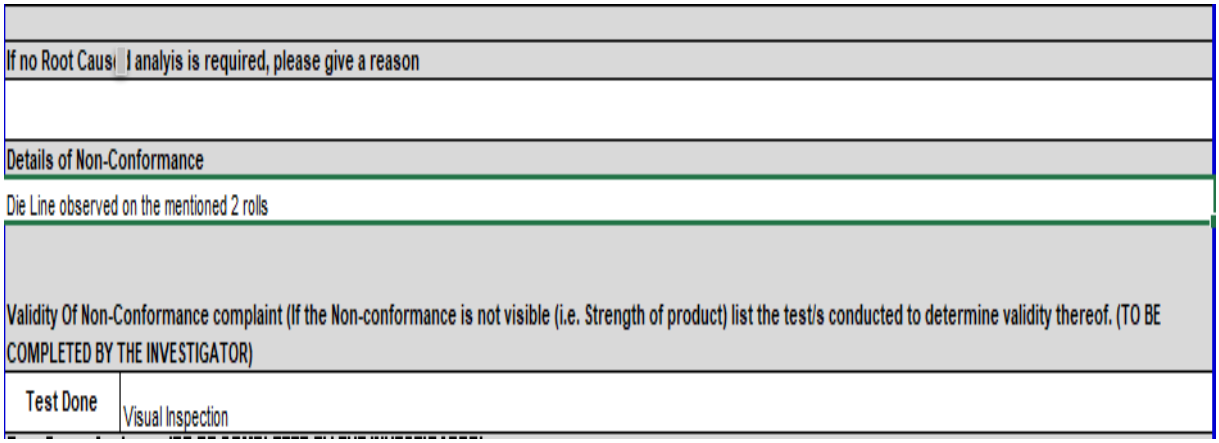


Figure 4.16: Details of the non-conformance origin

4.7.1.2 Section 2 - Tests for non-conformance validation for DIE line

Figure 4.17 illustrates details of tests for non-conformance validation and full details of the non-conformance and specification of the non-conformance.

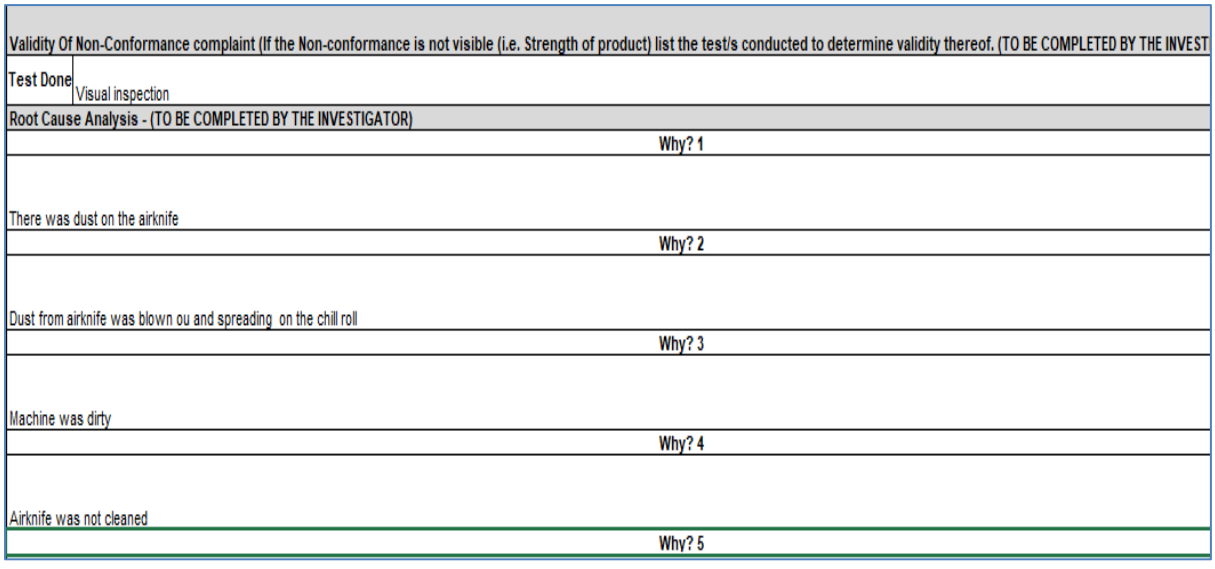


If no Root Caus l analyis is required, please give a reason
Details of Non-Conformance
Die Line observed on the mentioned 2 rolls
Validity Of Non-Conformance complaint (If the Non-conformance is not visible (i.e. Strength of product) list the test/s conducted to determine validity thereof. (TO BE COMPLETED BY THE INVESTIGATOR)
Test Done: Visual Inspection

Figure 4.17: Details of tests conducted to verify the raised non-conformance

4.7.1.3 Section 3 - Performance of the 5 Whys analysis for DIE line

Figure 4.18 illustrates the performance of the 5 Whys analysis in order to find different reasons for the defect occurrences.



Validity Of Non-Conformance complaint (If the Non-conformance is not visible (i.e. Strength of product) list the test/s conducted to determine validity thereof. (TO BE COMPLETED BY THE INVEST
Test Done: Visual inspection
Root Cause Analysis - (TO BE COMPLETED BY THE INVESTIGATOR)
Why? 1
There was dust on the airknife
Why? 2
Dust from airknife was blown ou and spreading on the chill roll
Why? 3
Machine was dirty
Why? 4
Airknife was not cleaned
Why? 5

Figure 4.18: 5 Whys analysis for problem clarification

4.7.1.4 Section 4 - Root cause analysis for DIE line

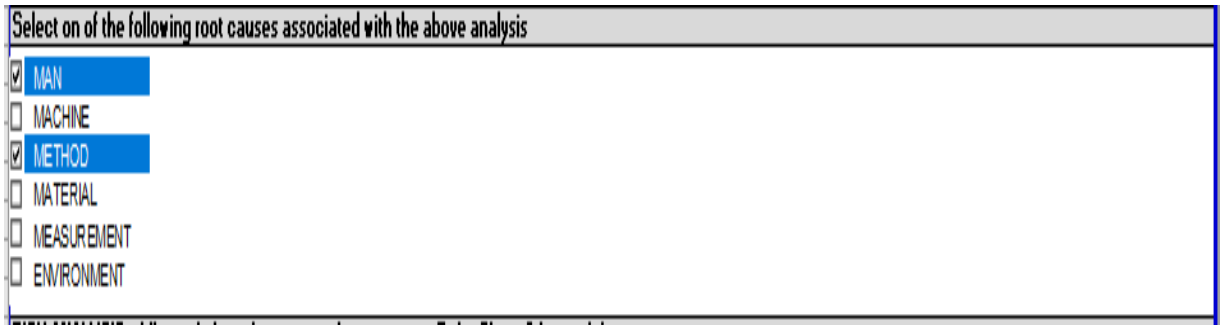


Figure 4.19: Root cause of the defect highlighted in blue

4.7.1.5 Section 5 - Risk analysis of defect and corrective action for DIE line

Figure 4.20 illustrates risk analysis of the defect, corrective action, how the defect can be prevented from re-occurring and the action plan.

RISK ANALYSIS - What risk does this pose to the customer. Refer Sheet 2 for guidelines

Risk ID	Risk/ Threat Description	Consequences	L	C	RR	Control
1	POOR HOUSEKEEPING IS A THREAT TO THE PRODUCT	Delays on lead times	Unlikely	Minor	4	Make use of machine cleaning check list

Likelihood of Occurrence Lookup Table					Consequence if Event Occurs Lookup Table				
Frequently	Likely	Moderate	Unlikely	Improbable	significan	Minor	Moderate	Major	Catastrophic
5	4	3	2	1	1	2	3	4	5

OPPORTUNITIES	ACTION PLAN	DUE DATE	RESPONSIBLE
5s implementation,cost reduction due to low scrap rate,Morale Increase	Cleaning Schedule was created and 5S Training	30/4/2020	Section In charge

Correction (TO BE COMPLETED BY INVESTIGATOR) - What immediate Corrective action was taken to solve the problem?

The production line was Stopped and cleaned

Figure 4.20: Problem ratings and corrective action

4.7.2 High gauge variation

Figures 4.21 to 4.23 represent high gauge variation non-conformance due to the fan on the machine not working properly. The fan was repaired and the product was reworked and sold as B grade.

4.7.2.1 Section 1 - Origin of the non-conformance

Figure 4.21 illustrates the origin of the non-conformance, item code, batch rejected, operator's name and area of the defect occurrence.

CORRECTIVE ACTION/PREVENTATIVE ACTION RCA FEEDBACK FORM - QA-F-44

NCI

Non Conformance Record Number : (Alert Number if a Defect)	013/04/2020	Date: 26/4/2020	Operator Name	Ujwal
Origin of Non Conformance:	Castline		Reel Numbers	SJD200030704
Item Code	SZ18-TVA01		Person who found the non conformance	Mbali & Thamie
Quantity Rejected	8238kg (1 roll)		Issued to:	Castline Operator
Design	Metallized film		Machine	Castline

- ☐ FOOD SAFETY
- ☐ SLITTING DEFECT
- ☑ METALLIZER DEFECT
- ☐ BOPP LINE
- ☐ PACKING
- ☐ RAW MATERIAL
- ☐ MATERIAL DAMAGE
- ☐ OTHER
- ☐ SAFETY

Root Causes Analysis Required?
- ◉ Yes
- ○ No

If no Root Caused analyis is required, please give a reason

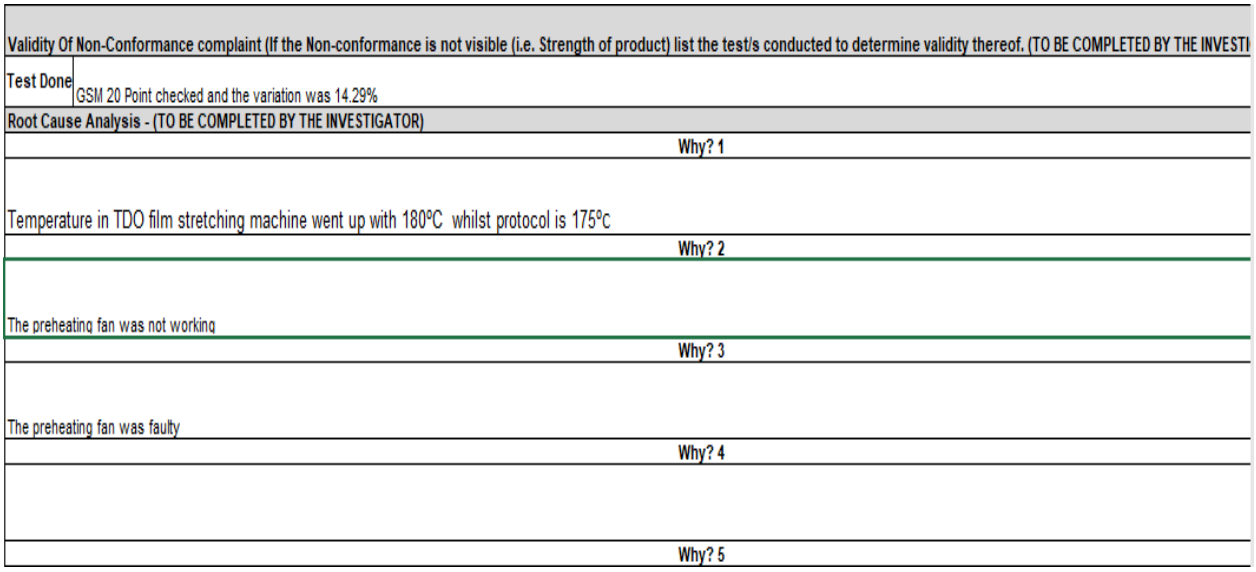
Details of Non-Conformance

High Gauge Variation

Figure 4.21: Details of non-conformance origin

4.7.2.2 Section 2 - 5 Whys analysis

Figure 4.22 illustrates the 5 Whys analysis that was performed in order to find different reasons for the defect occurrence.

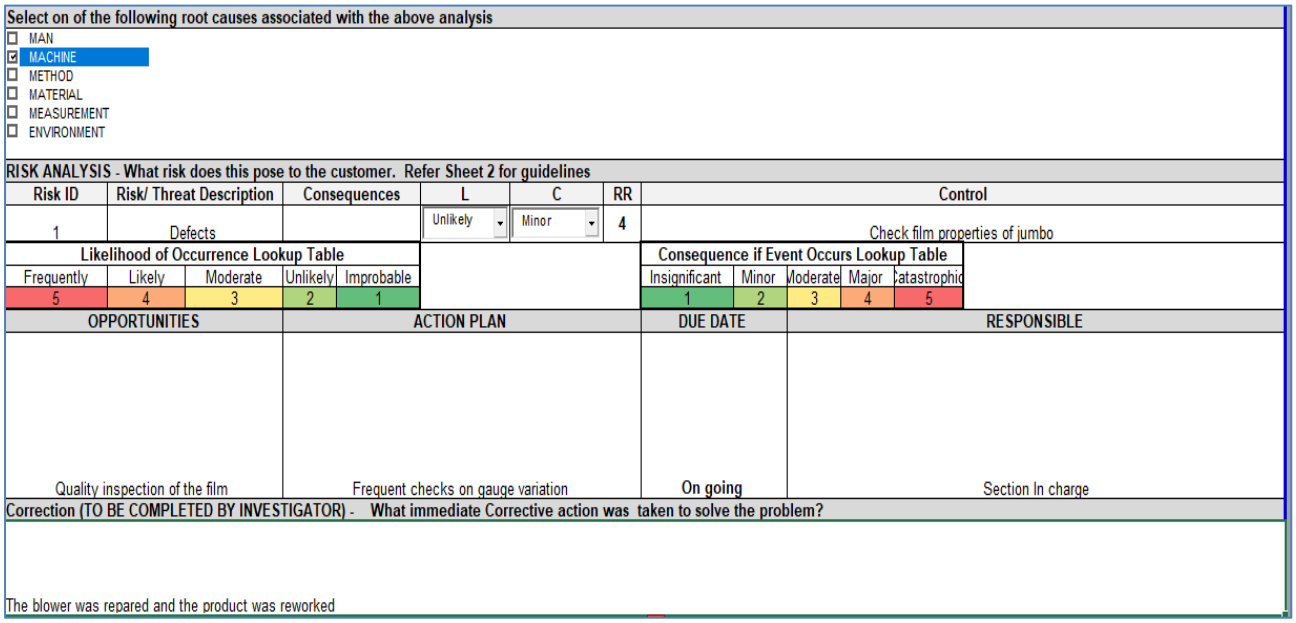


Validity Of Non-Conformance complaint (If the Non-conformance is not visible (i.e. Strength of product) list the test/s conducted to determine validity thereof. (TO BE COMPLETED BY THE INVESTI	
Test Done	GSM 20 Point checked and the variation was 14.29%
Root Cause Analysis - (TO BE COMPLETED BY THE INVESTIGATOR)	
Why? 1	
Temperature in TDO film stretching machine went up with 180°C whilst protocol is 175°c	
Why? 2	
The preheating fan was not working	
Why? 3	
The preheating fan was faulty	
Why? 4	
Why? 5	

Figure 4.22: Performance of the 5 Whys analysis

4.7.3.3 Section 3 - Root cause analysis for high gauge variation

Figure 4.23 illustrates the root cause analysis highlighted in blue, the risk analysis of the defect, corrective action and prevention of the defect re-occurrences.



Select on of the following root causes associated with the above analysis

- ☐ MAN
- ☑ MACHINE
- ☐ METHOD
- ☐ MATERIAL
- ☐ MEASUREMENT
- ☐ ENVIRONMENT

RISK ANALYSIS - What risk does this pose to the customer. Refer Sheet 2 for guidelines

Risk ID	Risk/ Threat Description	Consequences	L	C	RR	Control
1	Defects		Unlikely	Minor	4	Check film properties of jumbo

Likelihood of Occurrence Lookup Table				
Frequently	Likely	Moderate	Unlikely	Improbable
5	4	3	2	1

Consequence if Event Occurs Lookup Table				
Insignificant	Minor	Moderate	Major	Catastrophic
1	2	3	4	5

OPPORTUNITIES	ACTION PLAN	DUE DATE	RESPONSIBLE
Quality inspection of the film	Frequent checks on gauge variation	On going	Section In charge

Correction (TO BE COMPLETED BY INVESTIGATOR) - What immediate Corrective action was taken to solve the problem?

The blower was repared and the product was reworked

Figure 4.23: Ishikawa analysis and problem ratings

4.8 Control results of the semi-automated model

Below is the status of the semi-automated method that was introduced in order to achieve the goals of this research. The semi-automated model resulted in a smooth flow standardized procedure of non-conformance closure; hence, the international audit for the current financial year was successful and the major finding was closed. For further analysis it was evaluated that since film is recyclable, whenever a defect arises the system can be improved by finding other possible ways that can assist in expediting the recycle process. Below is an illustration of non-conformance closure in figures 4.24 after the implementation of the semi-automated model, which at 90% consistent due to the nature of defects some are awaiting for machinery parts to be closed, this method also evaluated some more improvements on maintenance schedules.

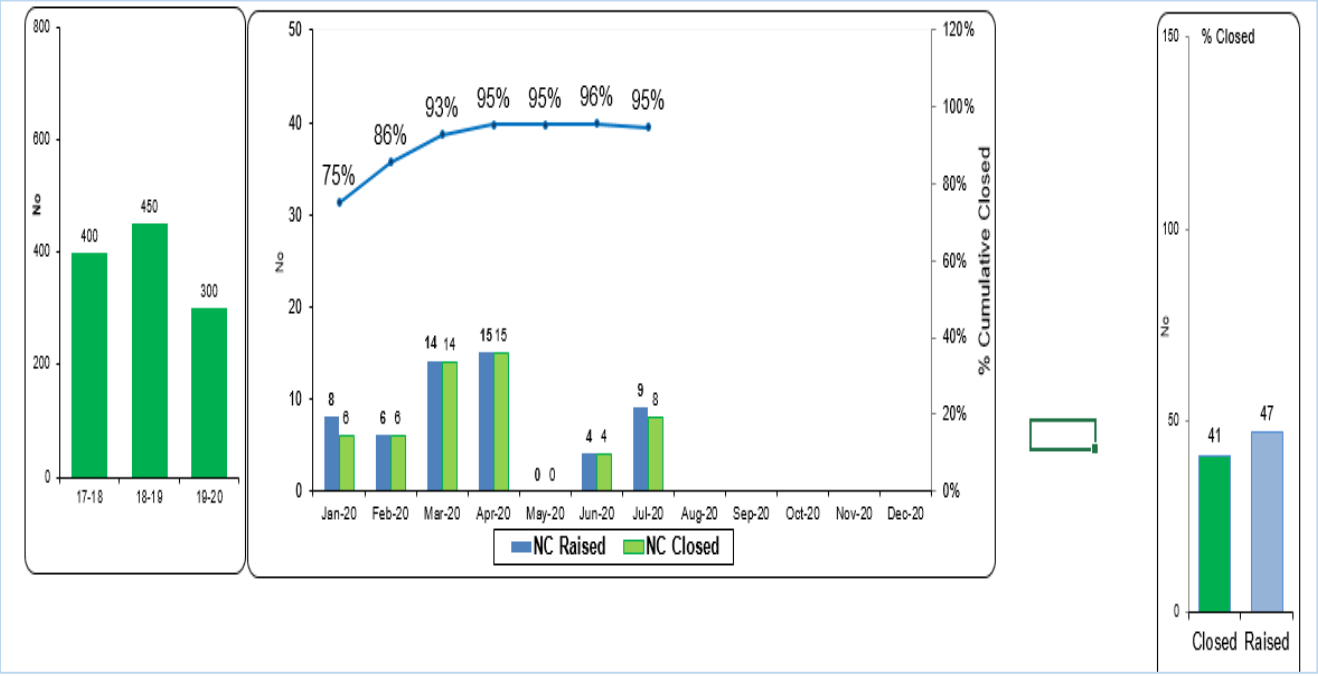


Figure 4.24: Illustration of non-conformance closure

4.9 Improvement results from the semi-automated model

The non-conformance closure clearly identified another opportunity for improvement which was to evaluate ways of recycling the product because most of the defects that emanate from the production line are recyclable. The production can be improved by doing it the correct way the first time with zero defects; however, the recycle process is part of the film trouble-shooting process. There was one way to recycle the film before the semi-automated model for non-conformance was introduced, which was the re-granulation system. Re-granulation is a system where the film scraps are melted into granules; these granules are then mixed with the film recipe to produce new film.

The proposed method was to feed the scraps directly into the grinder that cuts the film into finer particles and feeds them directly to the main extruder. This extruder is kept as a backup dosage in case there is any breakdown of the main extruder. The proposed recycle method reduces energy consumption because there is no re-granulation and it also reduces the cycle time for the recycling process. Below is an illustration of the current recycle method versus the proposed method.

4.9.1 Comparison between the old and the new recycle methods

Below in Figure 4.25 is an illustration of the differences between the old recycle process and the proposed new recycle process.

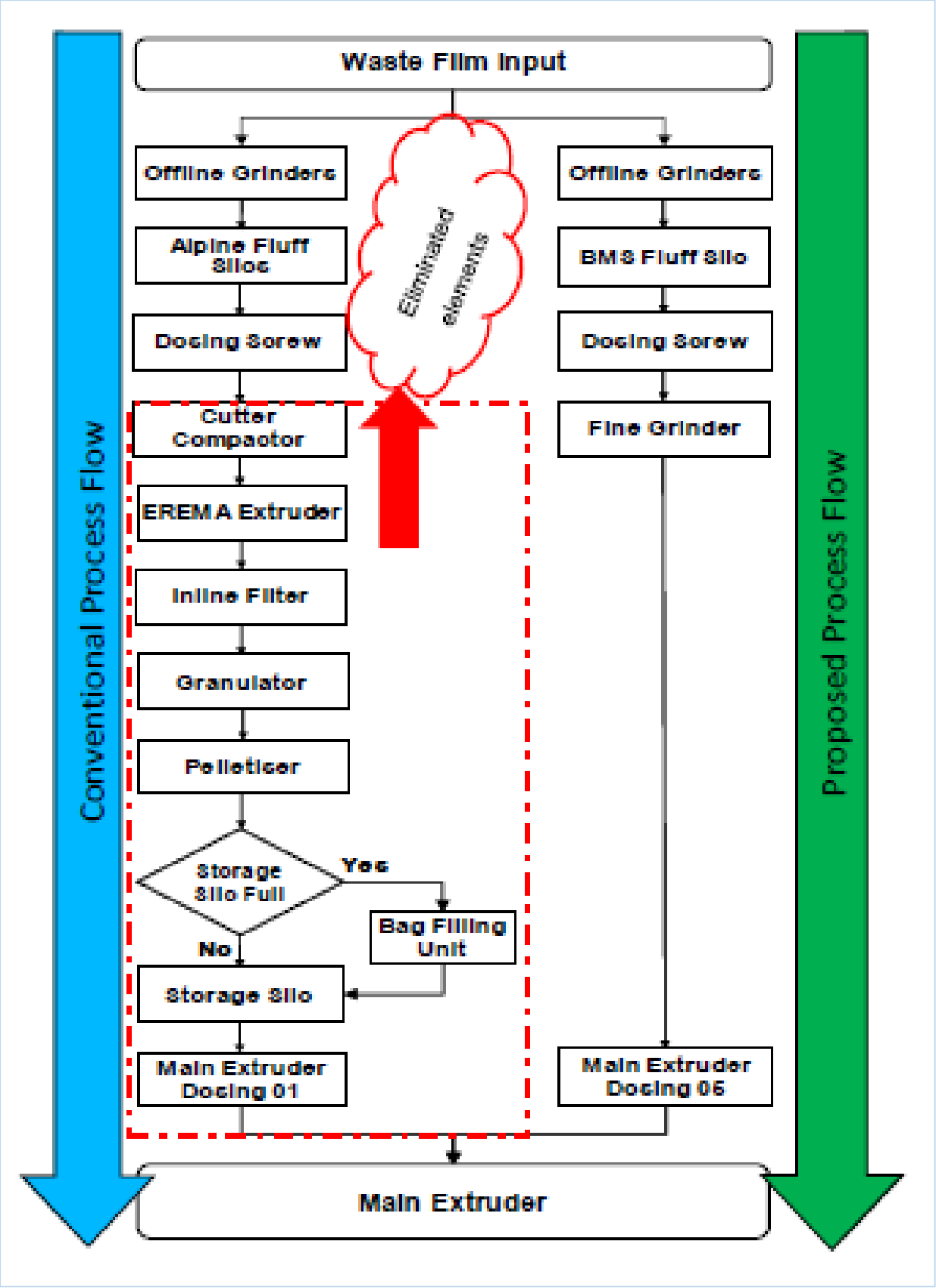


Figure 4.25 An illustration of the old and proposed new recycle methods

4.9.2 Schematic diagram of the new recycle method

Below is a schematic diagram of the proposed new recycle method that was implemented from process enhancement that was triggered by the semi-automated model for non-conformance closure.

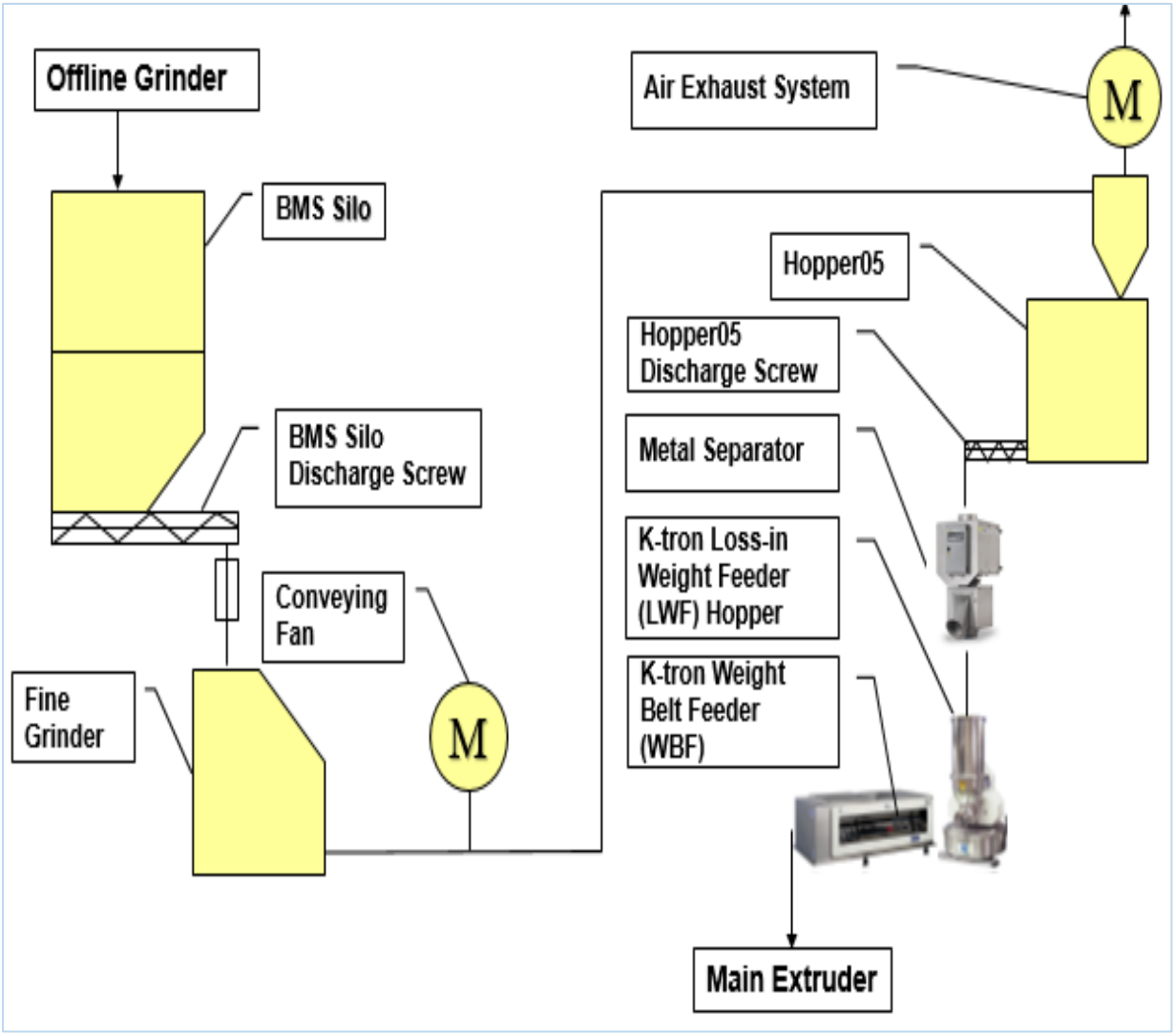


Figure 4.26: Illustration of the proposed new recycle method

4.9.3 Output rate of power consumption savings of the new recycle method

Below is an illustration of the output rate of the new recycle method versus the target, and the power consumption savings, comparing actual usage and the target usage.

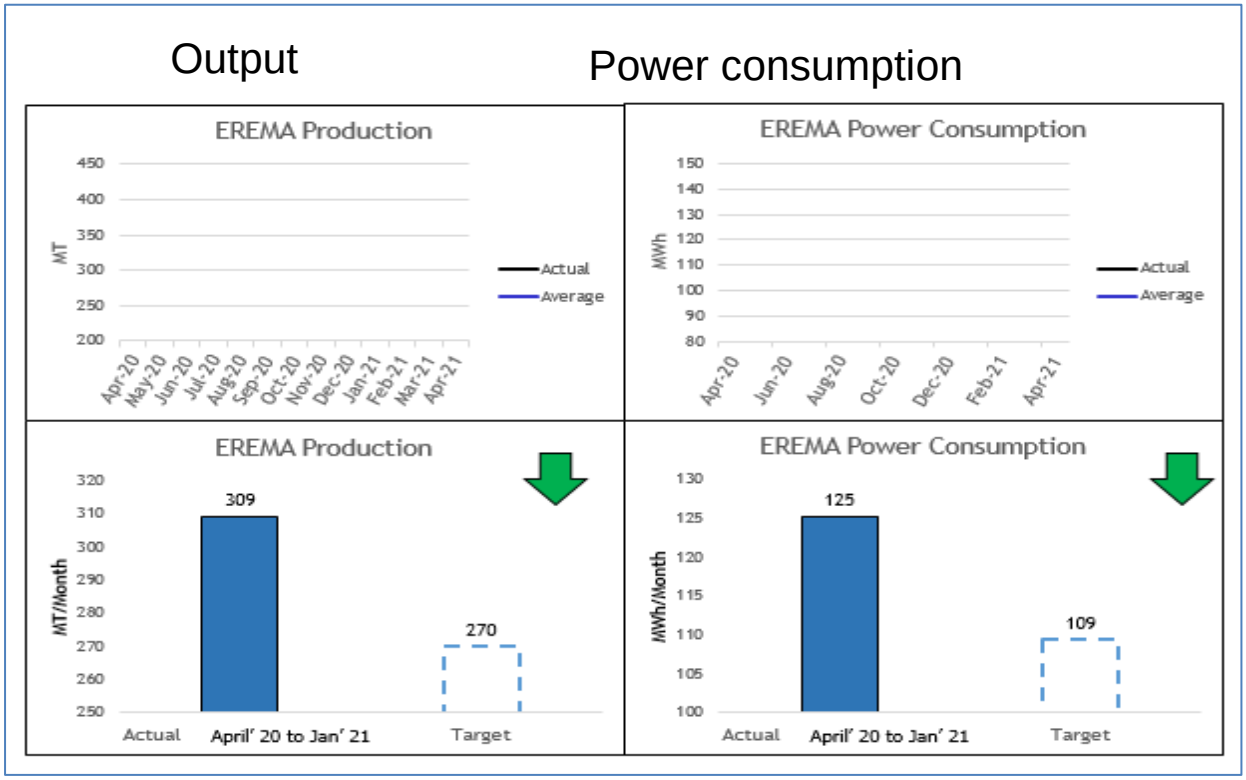


Figure 4.27: Illustration of output rate and power

4.10 Discussion of results

The new film recycle method mentioned above has resulted in huge savings. The target for savings was R168 000 and the current savings are R71 600 within the first six months of the current financial year (April 2020 - March 2021), meaning that the savings generated monthly amounts to R11 933.33. The table below has been constructed to illustrate process enhancement projects that have arisen after implementing an effective system for non-conformance closure. Industry 4.0 and Industry 5.0 are in line with continual improvement systems. The case study company has not yet reached industry 4.0 technology level; it is at an entry level due to the introduction of the semi-automated model which was constructed. There is thus a huge gap that can be filled by means of kaizen philosophy.

S.No.	Theme Desciption	Execution Themes	Saving to date (Zar)	Target Item & UOM
1	Reduce WIP Stock from 370 to 250MT (working capital reduction)	PFB-D-ET24	2400000	1 500 000
2	Eliminate Tight winding on film	PFB-D-ET01		180 000
3	Secure Coke Business	PFB-D-ET06		7 200 000
4	Achieve higher level BBBEE scorecard	PFB-D-ET09		
5	Improve Safety System & challenge external award	PFB-D-ET10		
6	Implement a Community Environmental Scheme	PFB-D-ET11		
7	Reduce waste to landfil by 50%	PFB-D-ET12	46000	550 000
8	Eliminate back treatment	PFB-D-ET13		1 600 000
9	Increase Castline Speed	PFB-D-ET14		809 700
10	Deckel Waste Reduction SZ to SCL	PFB-D-ET15	19000	3 118 000
11	Eliminate Crocodile skin	PFB-D-ET17		921 000
12	K Tron Fluff Consumption	PFB-D-ET18	71600	168 000
13	Implement HRMS (Sparsh)	PFB-D-ET19		
14	IT Enable NCR Management System	PFB-D-ET20		
15	Reduce Packing Cost	PFB-D-ET21	3195000	2 000 000
16	Increase Packing Material Collections	PFB-D-ET22	242400	3 000 000
17	Reduce Single Tier Pallets	PFB-D-ET23		840 000
18	Establish a Skills Transfer Program	PFB-D-ET25		
			5 974 000	**21 886 700**

Table 4.4: Illustration of proposed projects resulting from defects troubleshooting

4.12 Conclusion

The mentioned problem statement of oil drops has been resolved by implementing a project to install a duct which will assist in reducing the level of oil evaporation during the cooling process. The semi-automated model for the corrective action plan was successfully implemented in the case study company in order to satisfy the objectives mentioned in chapter 3. The study has proved that an integration of lean tools has resulted in continuous improvement due to the existence of an effective non-conformance closure system. This method has resulted in considerable improvements which have given the business confidence about adherence to international standards.

CHAPTER 5 : RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

In the previous chapters the structure of the research has been illustrated. Different chapters have highlighted the continuous improvement culture that has been adopted by the case study company. The flexibility of an application of lean tools has been reflected in each chapter; this has enabled one to conclude that an application of lean tools could result in substantial improvements. The main focus of this chapter is the recommendations for further improvements and the conclusion of the research. The recommendations to be adopted by the case study company are discussed in detail in this chapter.

5.2 Research findings and conclusions

The first objective was to define the ISO standards requirements in order to evaluate factors contributing to the inconsistency method of non-conformance closure that was initially used and identify the gap that resulted from the major finding. Requirements for ISO standards and various factor that contributes to the inconsistency of non-conformance closure were outlined and thus the first objective was accomplished.

The second objective was to measure the current situation, finding the root cause and demonstrating the non-conformances raised.The results revealed that there was a high number of unattended non-conformances which were reflecting as opened. It was therefore concluded that the procedure used for non-conformance closure was inadequate, thus the second objective was accomplished.

The third objective of the study was to construct a Microsoft excel semi-automated model for non-conformance closure. The results revealed that there was a need for a solid flexible system that can eliminate factors contributing to the inconsistency of non-conformance closure system It was therefore concluded that Microsoft excel can assist in creating a semi-automated model for non-conformance closure.

Objective number four was to demonstrate an application of the semi-automated model on the non-conformances raised within production in the case study.The results revealed

that manual closure of non-conformances can results to an inaccuracy of data hence closure can be delayed It was therefore concluded that there is a need for a flexible tool to be constructed using lean six sigma techniques, and thus the fourth objective was achieved.

5.3 Recommendations

5.3.1 Non-conformance closure software

Today many manufacturing sectors are striving to be world class. In order to be world class, an organization should adhere to good quality international standards. Now this poses the question, ‘what should be done in order to create a continuous loop system that would be more efficient to control quality systems and ensure that an organization is in line with the standards requirements?’ According to the notable improvement of the non-conformance model that has been illustrated in previous chapters, it could be recommended that an integration of lean principles software could be more efficient.

5.3.2 Development of fully automated software for non-conformance closure

It was also recommended to develop a fully automated software for non-conformance closure system. Below is an illustration of the non-conformance software input.

- Step number one

  Details of non-conformance found by recording information provided from a what, where, when, who questionnaire and the name of the process can be logged.

- Step number two

  Step number two entails a deep analysis of the problem by means of 5Whys, Ishikawa and seven types of waste classification.

- Step number three

Step number three describes the counter measures required to fix the problem, that is, corrective actions that have to be or have been taken.

- Step number four

Step number four outlines the risks and opportunities presented by the findings raised

Below if the process flow of how the input parameters for a recommended fully automated software, the proposed software is further illustrated as a frame display on figure 5.2

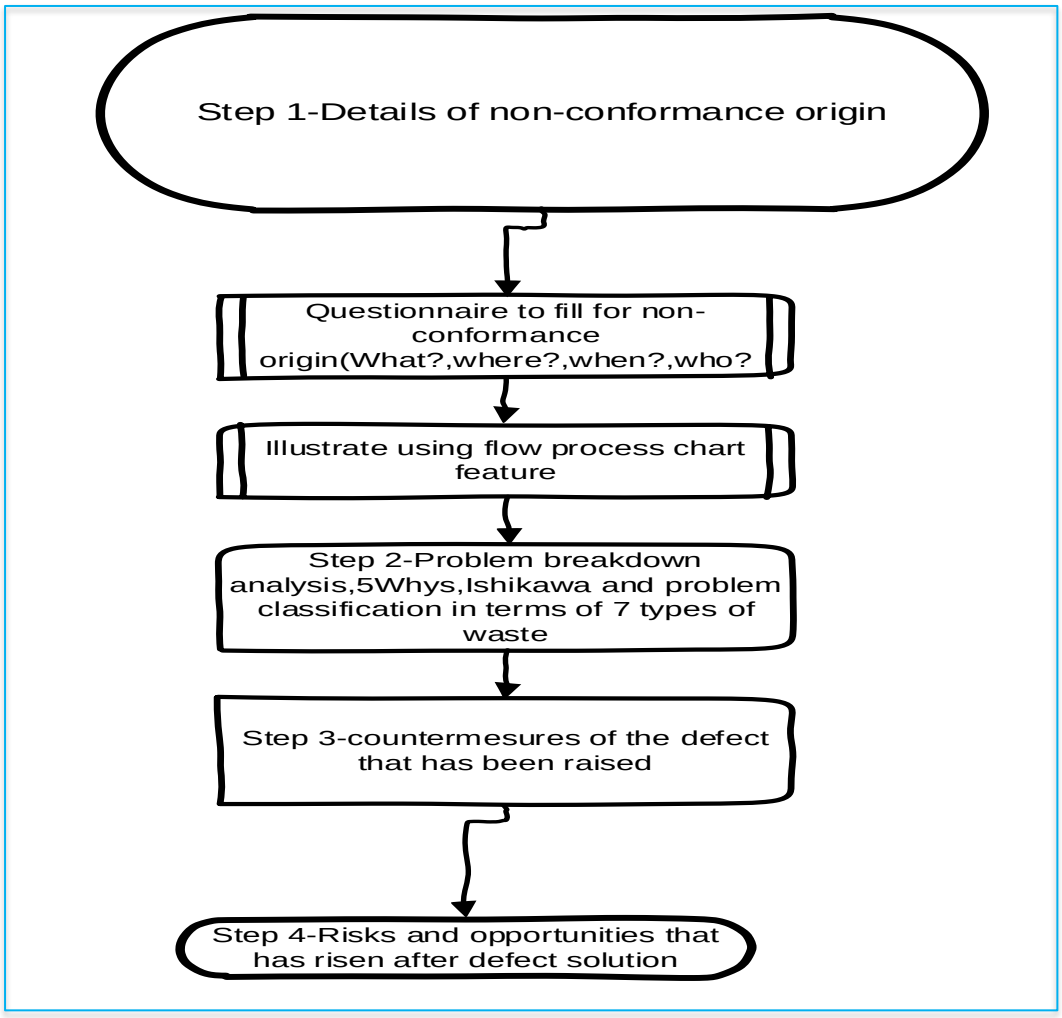


Figure 5.1: Flow process chart for input parameters of the proposed software

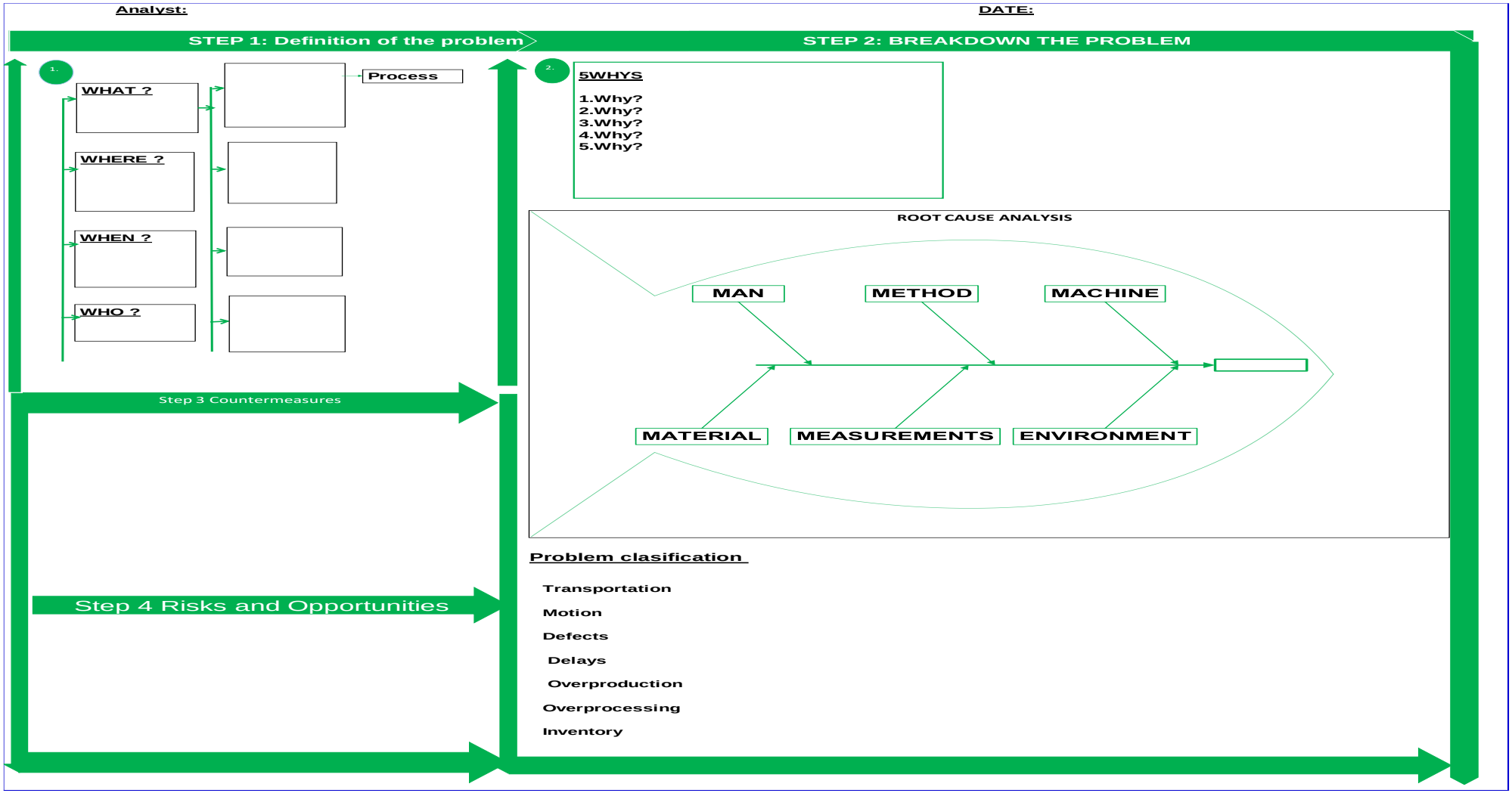


Figure 5.2: Illustration of proposed software input parameters frame

5.3.3 Integration of Quality non-conformances and Safety risks

A process with a zero defect rate results in fewer safety risks; hence one can conclude that a combination of quality systems and safety measures should be recommended. The case study company currently uses a quality system model to close non-conformances and a separate system to investigate incidents as well as safety findings. Working with the same system that is a combination of different functions in an organization results in team work and considerable continuous improvement; such recommendations complement the objectives of this research.

5.4 Area for further research

A smooth flow non-conformance system results in a world class business. Even though there is no specific area where one could implement a smooth flow system for non-conformance closure, it is important for any business to maintain a good system of non-conformance closure. The area of research for smooth flow non-conformance closure should be any business that is working on adherence to ISO standards.

5.5 Conclusion

The objective of this research was to utilise lean principles in order to accelerate the rate of kaizen in the film packaging industry. The DMAIC approach was used to carry out each evaluation of the research; an integration of lean tools, Ishikawa, and 5Whys was performed. A non-conformance closure model was constructed and applied which resulted in substantial improvement. Furthermore, recommendations were suggested for a process of continual improvement. It can thus be concluded that lean tools complement the rate of kaizen implementation.

References

[1] Rachman, A. and Ratnayake, R.C., 2019. Adoption and implementation potential of the lean concept in the petroleum industry: state-of-the-art. *International Journal of Lean Six Sigma*, pp.311-338.

[2] Gaikwad, L. and Sunnapwar, V., 2020. An integrated Lean, Green and Six Sigma strategies. *The TQM Journal*, pp.201-205.

[3] De Melo, V.V., 2014, July. Kaizen programming. In *Proceedings of the 2014 Annual Conference on Genetic and Evolutionary Computation* (pp. 895-902).

[4] Dimitrescu, A., Alecusan, A.M., Babis, C. And Dascalu, L., 2018. Elimination of Losses Using Lean Manufacturing Techniques and Kaizen Philosophy. *Fiability & Durability/Fiabilitate si Durabilitate*, (2), pp.61.

[5] Rüttimann, B.G. and Stöckli, M.T., 2016. Going beyond triviality: The Toyota production system—lean manufacturing beyond Muda and Kaizen. *Journal of Service Science and Management*, *9*(02), p.140.

[6] Ivana, P., Ivana, I., Miroslava, P. and Branka, M., 2019. Kaizen as the Element of Overall Management Quality Control. *No. 25 Int'l J. Econ. & L.*, *9*, pp 134.

[7] Soundararajan, K., 2019. Cost-reduction and quality improvement using DMAIC in the SMEs. *International Journal of Productivity and Performance Management*.

[8] Darmawan, H., Hasibuan, S. and Hardi-Purba, H., 2018. Application of Kaizen Concept with 8 Steps PDCA to Reduce in Line Defect at Pasting Process: A Case Study in Automotive Battery. *Int. J. Adv. Sci. Res. Eng*, *4*, pp.99.

[9] Silva, M.G.A. and de Alencar, D.B., 2019. PDCA application as a management tool in professional qualification course. *Itegam-Jeta*, 5(20), pp.12-15.

[10] Garza-Reyes, J.A., Romero, J.T., Govindan, K., Cherrafi, A. and Ramanathan, U., 2018. A PDCA-based approach to environmental value stream mapping (E-VSM). *Journal of Cleaner Production*, *180*, pp.335-348.

[11] Shingo, S., 2018. *The sayings of Shigeo Shingo: Key strategies for plant improvement*. Routledge.

[12] Otur, B., Yildirim, I.S. and Ayhan, M.B., 2018. Single minutes exchange of die (SMED) applications at the color changeover process of plastic bottles. *PressAcademia Procedia*, *7*(1), pp.234.

[13] Corona, E. and Pani, F.E., 2013. A review of lean-kanban approaches in the software development. *WSEAS transactions on information science and applications*, *10*(1), pp.3.

[14] Măgdoiu, A. and Oprean, C., 2014. Broadening the concept of pokayoke beyond the automotive industry. *ACTA Universitatis Cibiniensis*, *65*(1), pp.54.

[15] Tekin, M., Arslandere, M., Etlioğlu, M., Koyuncuoğlu, Ö. and Tekin, E., 2018, August. An Application of SMED and Jidoka in Lean Production. In *The International Symposium for Production Research*, pp. 536-537.

[16] Bhat, R., Mohan, N., Naidu, M. and Shivamurthy, S., 2018. Reducing the Production Lead Time of an Industry Using Value Stream Mapping Integrated with Kaizen. *International Journal of Engineering and Technology (UAE)*, *7* (4.41 Special Issue 41), pp.21-23.

[17] Trebuna, P., Pekarčíková, M. and Edl, M., 2019. Digital value stream mapping using the Tecnomatix Plant Simulation software. *International Journal of Simulation Modelling*.pp19.

[18] Ghushe, S., Deshmukh, S., Basgoti, V., Yawale, Y., Gangasagar, P. and Duryodhan, N.S., 2017. Implementation of Value Stream Mapping (VSM) In a Coir Product Manufacturing Industry. *International Research Journal of Engineering and Technology*, *4*(4), pp.457-462.

[19] Górny, A., 2017. Identification of occupational accident causes by using the Ishikawa diagram and Pareto principles. *Economics & Management 1*(1), pp.384-388.

[20] Stefanovic, S., Kiss, I., Stanojevic, D. and Janjic, N., 2014. Analysis of technological process of cutting logs using Ishikawa diagram. *Acta Technica Corviniensis-Bulletin of Engineering*, *7*(4), p.94-96.

[21] Hekmatpanah, M., 2011. The application of a cause and effect diagram in the oil industry in Iran: The case of four liter oil canning process of Sepahan Oil Company. *African Journal of Business Management*, *5*(26), p.10901.

[22] De Araujo, L.F. and De Queiroz, A.A., 2009, September. A conceptual model for production leveling (heijunka) implementation in batch production systems. In *IFIP International Conference on Advances in Production Management Systems* (pp. 81-88). Springer, Berlin, Heidelberg.

[22] Cherrafi, A., Elfezazi, S., Hurley, B., Garza-Reyes, J.A., Kumar, V., Anosike, A. and Batista, L., 2019. Green and Lean: a Gemba–Kaizen model for sustainability enhancement. *Production Planning & Control*, pp.385-399.

[23] Shafiq, M., Zhang, Q., Akbar, M.A., Khan, A.A., Hussain, S., Amin, F.E., Khan, A. and Soofi, A.A., 2018. Effect of project management in requirements engineering and requirements change management processes for global software development. *IEEE Access*, *6*, pp.25747-25763.

[24] Vashisht, V., Lal, M. and Sureshchandar, G.S., 2016. Defect prediction framework using neural networks for software enhancement projects. *Journal of Advances in Mathematics and Computer Science*, pp.1-12.

[25] Sani, M.F., Van Zelst, S.J. and Van der Aalst, W.M. 2017, September. Improving process discovery results by filtering outliers using conditional behavioural probabilities. In *International Conference on Business Process Management* pp. 216-229.

[26] Bolpagni, M., Burdi, L. and Ciribini, A.L.C., 2017. Integration of lean construction and building information modelling in a large client organization in Massachusetts. *LC3*, *2*, pp.9-12.

[27] Leme, R., Nunes, A., Message Costa, L. and Silva, D, 2018. Creating value with less impact: Lean, green and eco-efficiency in a metalworking industry towards a cleaner production. *Journal of Cleaner Production*, 196, pp.517-534.

[28] Dave, B., Kubler, S., Främling, K. and Koskela, L., 2016. Opportunities for enhanced lean construction management using Internet of Things standards. *Automation in construction*, *61*, pp.86-97.

[29] Marques, P.A., Saraiva, P.M., Requeijo, J.G. and Guerreiro, F.J., 2011, September. Integration of Six Sigma with a QMS based on the ISO 9001 requirements: a Portuguese SME case study. In *2011 IEEE International Conference on Quality and Reliability*, pp. 391-397.

[30] Marques, P.A., Guerreiro, F.F. and Saraiva, P.M., 2019. Lean Six Sigma methods and tools in ISO 9001: 2015 management systems.

[31] Alatulkkila, S., 2018. Quality nonconformity data management in Electrical Motor Manufacturing, pp.1-81.

[32] Nováková, R., Šujanová, J. and Pauliková, A., 2017. Use of 8D Method in Nonconformity Resolution–a Case Study of Production of Spliced Veneers in Slovakia. *Drvna industrija: Znanstveni časopis za pitanja drvne tehnologije 68*(3), pp.249-290.

[33] Chen, H., Liu, S. and Oderanti, F., 2020. A knowledge network and mobilisation framework for lean supply chain decisions in the agri-food industry. In *Supply Chain and Logistics Management: Concepts, Methodologies, Tools, and Applications*, pp.44.

[34] Van der Vorst, J.G., Van Dongen, S., Nouguier, S. and Hilhorst, R., 2002. E-business initiatives in food supply chains: definition and typology of electronic business models. *International Journal of Logistics*, *5*(2), pp.120.

[35] Afonso, H. and do Rosário Cabrita, M., 2015. Developing a lean supply chain performance framework in a SME: a perspective based on the balanced scorecard. *Procedia Engineering*, *131*, pp.273.

[36] Benešová, A., Hirman, M., Steiner, F. and Tupa, J., 2019. Determination of Changes in Process Management within Industry 4.0. *Procedia Manufacturing*, *38*, pp.1692.

[37] Zasadzień, M., 2020. Improving Work Organisation in the Production Hall-a Case Study. , pp.327-350.

[38] Karadayi-Usta, S., 2019. An interpretive structural analysis for industry 4.0 adoption challenges. *IEEE Transactions on Engineering Management*.pp.1.

[39] Kipper, L.M., Furstenau, L.B., Hoppe, D., Frozza, R. and Lepsen, S., 2019. Scopus scientific mapping production in industry 4.0 (2011–2018): a bibliometric analysis. *International Journal of Production Research*, pp.12.

[40] Junker, B, 2010. Kaizen for improvement of rapid protein production for early reagent protein quantities. *Biochemical Engineering Journal*, 49(3), pp.435-444.

[41] Choomlucksana, J., Ongsaranakorn, M. and Suksabai, P, 2015. Improving the Productivity of Sheet Metal Stamping Sub-assembly Area Using the Application of Lean Manufacturing Principles*. Procedia Manufacturing,* 2, pp.102-107.

[42] Rohani, J. and Zahraee, S, 2015. Production Line Analysis via Value Stream Mapping: A Lean Manufacturing Process of the Color Industry. Procedia Manufacturing, 2, pp.6-10.

[43] Veloso de Melo, V. and Banzhaf, W., 2017. Improving the prediction of material properties of concrete using Kaizen Programming with Simulated Annealing. *Neurocomputing,* 246, pp.25-44.

[44] Nedeliakova, E., Stefancova, V. and Kudlac, S, 2017. Six Sigma and Dynamic Models Application as an Important Quality Management Tool in Railway Companies. *Procedia Engineering*, 187, pp.242-248.

[45] Oliveira, J., Sa, J. and Fernandes, A, 2017. Continuous improvement through "Lean Tools": An application in a mechanical company. *Procedia Manufacturing*, 13, pp.1082-1089.

[46] Arunagiri, P. and Gnanavelbabu, A, 2014. Identification of High Impact Lean Production Tools in Automobile Industries using Weighted Average Method. *Procedia Engineering*, 97, pp.2072-2080.

[47] Baysan, S., Kabadurmus, O., Cevikcan, E., Satoglu, S. and Durmusoglu, M, 2019. A simulation-based methodology for the analysis of the effect of lean tools on energy efficiency: An application in the power distribution industry. *Journal of Cleaner Production*, 211, pp.895-908.

[48] Roriz, C., Nunes, E. and Sousa, S 2017. Application of Lean Production Principles and Tools for Quality Improvement of Production Processes in a Carton Company. *Procedia Manufacturing*, 11, pp.1069-1076.

[49] Boronat, F., Budia, A., Broseta, E., Ruiz-Cerdá, J. and Vivas-Consuelo, D, 2018. Application of Lean Healthcare methodology in a urology department of a tertiary hospital as a tool for improving efficiency. *Actas Urological Española's (English Edition*), 42(1), pp.42-48.

[50] Monteiro, J., Alves, A. and Carvalho, M, 2017. Processes improvement applying Lean Office tools in a logistics department of a car multimedia components company. *Procedia Manufacturing*, 13, pp.995-1002.

[51] Omogbai, O. and Salonitis, K. 2016. Manufacturing System Lean Improvement Design Using Discrete Event Simulation. *Procedia CIRP*, 57, pp.195-200.

[52] Lock, C. and Reinhart, G. 2016. A Meta-model for Analysing the Influence of Production-related Business Processes. *Procedia CIRP*, 57, pp.79-84.

[53] Correia, D., Silva, F., Gouveia, R., Pereira, T. and Ferreira, L. 2018. Improving manual assembly lines devoted to complex electronic devices by applying Lean tools. *Procedia Manufacturing*, 17, pp.663-671.

[54] Rauch, E., Damian, A., Holzner, P. and Matt, D. 2016. Lean Hospitality - Application of Lean Management Methods in the Hotel Sector. *Procedia CIRP*, 41, pp.614-619.

[55] Lellis, A., Leva, A. and Sulis, E. 2018. Simulation for change management: an industrial application. *Procedia Computer Science*, 138, pp.533-540.

[56] Neves, P., Silva, F., Ferreira, L., Pereira, T., Gouveia, A. and Pimentel, C. (2018). Implementing Lean Tools in the Manufacturing Process of Trimmings Products. *Procedia Manufacturing*, 17, pp.696-704.

[57] Quadracci, L.J. and Warn, B. Boeing Co., 2019. *Associative memory learning agent for analysis of manufacturing non-conformance applications*. U.S. Patent, pp.1-2.

[58] Hinsch, M., 2019. Quality and Safety Management. In *Industrial Aviation Management*,pp. 275-310. Springer, Berlin, Heidelberg.

[59] Nurjannah, N., 2020. Effects of environmental characteristics and business partner relationships on improving innovation performance through the mediation of knowledge management practices. *VINE Journal of Information and Knowledge Management Systems*.

[60] Batbooti, R.S., Ransing, R.S. and Ransing, M.R., 2015. Discover and embed product specific process knowledge in line with ISO9001: 2015 requirements. 45, p. 2015

Appendices

Appendix 1: Training certificate: Introduction to research ethics

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of the TRREE training programme in research ethics evaluation

Release Date: 2019/12/11
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Appendix 2: SGS Summary for audit report

1. Audit objectives

The objectives of this audit were:
To determine conformity of the management system, or parts of it with audit criteria and its:

- ability to ensure applicable statutory, regulatory, and contractual requirements are met,
- effectiveness to ensure the client can reasonably expect to achieve specified objectives, and
- ability to identify as applicable areas for potential improvement.

Note: This audit was conducted remotely from the Lead Auditor's office with the use of ICT tools such as Microsoft Teams, Emails and Whats App, to carry out audit activities including the collection of audit evidence that was requested from the client (due to COVID-19 restrictions).

2. Scope of certification

- Manufacture of polypropylene film
- Exclusions (ISO9001:2015):
  - 7.3 Design and Development, has been procured by outside vendor to procure BOPP Manufacturing Technology as the organisation is international.
  - 7.5.2 Validation of processes as processes for production and service provision validated by SRF Head Office.

Has this scope been amended as a result of this audit? ☐ Yes ☒ No

This is a multi-site audit and an Appendix listing all relevant sites and/or remote locations has been established (attached) and agreed with the client. ☐ Yes ☒ No

For integrated audits, confirm the current level of the client's IMS integration: ☐ N/A ☐ Basic ☒ High

4. Previous Audit Results

The results of the last audit of this system have been reviewed, in particular to assure appropriate correction and corrective action has been implemented to address any nonconformity identified. This review has concluded that:

☐ Any nonconformity identified during previous audits has been corrected and the corrective action continues to be effective. (Refer to Section 6 for details)

☒ The management system has not adequately addressed nonconformity identified during previous audit activities and the specific issue has been re-defined in the nonconformity section of this report.
Note: 3 previous NCs still to be verified at on-site audit scheduled on 17-21 Aug 2020, to test effectiveness of implementation.

5. Audit Findings

The audit team conducted a process-based audit focusing on significant aspects/risks/objectives. The audit methods used were interviews, observation of activities and review of documentation and records.

The management system documentation demonstrated conformity with the requirements of the audit standard and provided sufficient structure to support implementation and maintenance of the management system. ☐ Yes ☒ No

The organization has demonstrated effective implementation and maintenance / improvement of its management system and is capable of achieving its policy objectives, as well as the intended results of the respective management system(s). ☒ Yes ☐ No

The organization has demonstrated the establishment and tracking of appropriate key performance objectives and targets and monitored progress towards their achievement. ☒ Yes ☐ No

6. Significant Audit Trails Followed

The specific processes, activities and functions reviewed are detailed in the Audit Planning Matrix and the Audit Plan. In performing the audit, various audit trails and linkages were developed, including the following primary audit trails, followed throughout:

- **Relating to Previous Audit Results:**

Nonconformity	N° LG01 of 8	Satisfactorily closed:	☒ Yes ☐ No
Description of the Finding:	Corrective action on previous Major Nonconformity 08GMN was found to be partially undertaken. Same still remains as a Major Nonconformity: • No consistence in the adherence in the proposed closure dates on the Non-Conformances Reports over 90 days past due dates with no status recorded. • Correction, Corrective Action and Preventive Action Procedure: SYS-SOP-11 – risk & opportunities of the organisation were not adequately reviewed or updated for the NCRs raised.		
Evidence reviewed:	Refer to FUA Audit report 11 May 2019 for actions that deemed closure of this finding. SYS-SOP-11 Rev 4 updated to include the necessary changes: reviews of the non-conformances that were raised, root cause methodology required to be applied (5 whys) and risk and opportunities updated, as necessary. CAR meetings were held regularly to review and address CARs. Viewed Minutes of CAR (CAPA) meeting held 23 Feb 2020, which addressed key issues and actions of CAPAs to date.		
Conclusion:	**Corrective action has been taken and remains effective**		