The application of Lean Six Sigma in the train manufacturing industry to improve productivity.

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1. Chapter 1: Introduction

1.1 Research title

The application of Lean Six Sigma in the train manufacturing industry to improve productivity.

1.2 Statement of purpose

This research aims to assess how the application of Lean Six Sigma (LSS) principles improve efficiency and productivity in the train manufacturing industry.

1.3 Background of the study

The demand for trains is increasing globally as trains are the fastest and most affordable way to transport large numbers of passengers. A study by Niu et al. (2023), which compared rail transportation efficiency in 16 countries, also notes that the demand for trains is increasing. In addition to high transportation capacity trains are more affordable than cars and airplanes. Advantages of rail transportation also extend to environmental sustainability. Train travel consumes less energy than air or road travel, leading to lower carbon emissions. In fact, trains produce the lowest emissions among all transportation methods in urban areas (Cresci et al., 2019).

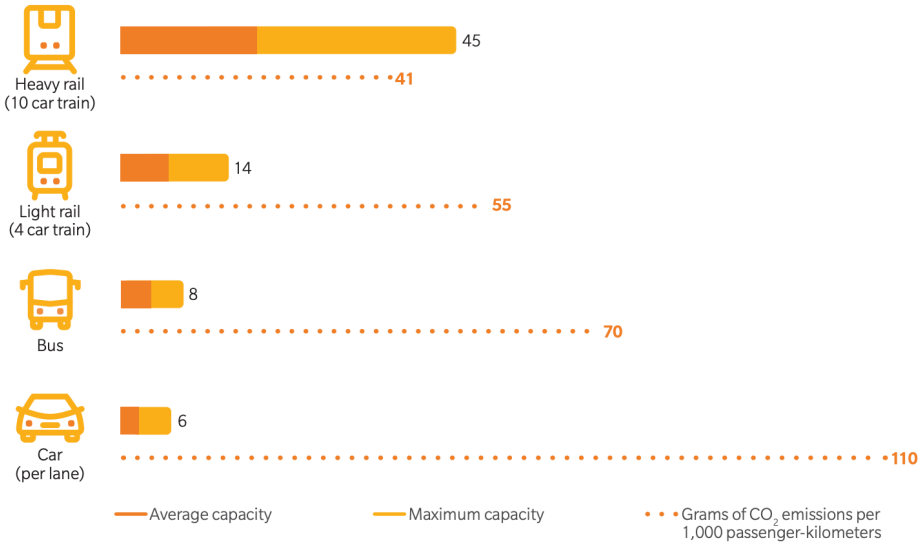

Figure 1: Urban commuting transport capacity and relative carbon emissions. Source: (Cresci et al., 2019)

After 10 years of implementing high-speed rail (HSR) in Italy, there was economic growth, increase in transport accessibility, and a positive general social impact. Low transport accessibility negatively impacts accessibility to job opportunities, health and education facilities (Cascetta, 2022). Such positive impacts have resulted in the substantial growth of the rail network worldwide including countries such as South Africa (Singh, 2021). South Africa boosts the most expansive rail network in Africa. The advantages that are witnessed globally with regards to rail are also present in South Africa with regards to economic growth, transportation efficiency, low carbon emissions and etc. However as noted in the National Development Plan (NDP) South Africa should invest in public transport to enhance the lives of low-income families. This investment would improve mobility, allowing these households better access to economic opportunities across different regions of the country (Hlatshwayo, 2022).

Challenges facing rail transport sector in South Africa include an aging fleet of commuter trains, cable theft and reduced freight capacity amongst others. In response to the challenges faced Gibela rail consortium as established to manufacture modern trains and increase the capacity of the rail sector. The rail sector needs to improve train manufacturing productivity to achieve this request. Productivity in manufacturing measures how efficiently a plant transforms inputs into outputs. It is usually expressed as the ratio of the amount produced to the resources used, such as labour, materials, and machinery. Boosting a manufacturing company's productivity is essential for securing significant profits in a competitive marketplace (Zubair et al., 2021). An increase in productivity reflects a plant's effective use of all resources to produce more goods or services while minimizing waste and expenses.

The LSS methodology removes waste, improves quality, and minimizes variation or defects within an organisation. LSS principles are centred on eliminating activities that do not add value and reducing overall cycle times (Ishak, 2020). Shreeranga Bhat. (2019) examined the different tools and techniques of LSS, including the Kanban system, 5S, Cause-and-Effect Analysis, and Value Stream Mapping (VSM), which facilitate these productivity enhancements.

The research seeks to apply the principles of LSS to enhance productivity in the train manufacturing industry.

1.4 Research problem

The rail Manufacturing industry faces challenges in delivering trains on time, with high quality, and at a cost-effective rate. This may be attributed to the low efficiency and productivity of the train manufacturers.

The PRASA CEO Zolani Matthews mentioned in the Engineering News that the train manufacturer Gibela signed an R53-billion contract to supply PRASA with 600 six-car trains for its Metrorail service by 2028. However, Matthews acknowledged that Gibela is behind schedule in delivering the new train sets to PRASA. He mentioned that Gibela might need to address specific issues related to these delays, with a PRASA team meeting weekly with Gibela to discuss the ongoing concerns (Venter, 2021).

Reuters also published an article about Bombardier facing penalties for delayed deliveries of rail cars in Toronto's Metrolinx. It was also mentioned that they are also facing performance problems and delivery delays in other contracts in New York and Switzerland (Reuters, 2019). The lack of performance can be attributed to the rail manufacturing plants over processing, performing non value adding activities and the results being poor deliveries to customer.

The above-mentioned projects were facing challenges attributed to low productivity and efficiency. To address these issues and improve manufacturing efficiency and productivity, this research will illustrate how the LSS approach can address productivity issues.

1.5 Research objectives

1. To explore challenges of productivity and efficiency in the train manufacturing industry.
2. To illustrate how the implementation of LSS, enhances train manufacturing productivity and efficiency.
3. To create a road map for effectively implementing LSS to improve productivity in the train manufacturing space.

1.6 Research questions

1. What factors might affect productivity in the rail manufacturing industry?
2. How can LSS be best applied to systematically enhance productivity in train manufacturing?

3. What is the roadmap to developing an effective implementation of LSS to improving productivity in a manufacturing environment?

1.7 Rationale of the study

There is a growing global demand for trains due to economic growth, improved transport accessibility, environment and social impacts. Rail traffic is expected to increase with technological advancements and infrastructure improvements (Singh, 2021).

In South Africa, investing in public transport is recommended to improve mobility and access to opportunities for low-income families (Hlatshwayo, 2022). To meet this demand, the train manufacturing sector must boost productivity by efficiently utilizing resources and minimizing waste. LSS is an effective methodology for enhancing productivity by eliminating non-value-adding activities, improving quality, and reducing defects and cycle times (Zubair, 2021). Therefore, the research aims to apply LSS principles to improve productivity in the train manufacturing sector.

1.8 Delimitations of the study

The research will not consider the financial implication of poor productivity since the financial implications indicate the magnitude of poor productivity and not the processes that lead to poor productivity which are of interest in this study.

It will not consider the difference in the train design since the difference in train design is subject to customer demand which is not of interest in this study.

1.9 Assumptions

The research assumes that the organisations and countries referenced understand LSS principles and acknowledge the need to enhance productivity. The study assumes that because a person is trained in LSS, then they know exactly what they are talking about in the interview.

1.10 Chapter outline

Chapter one, the introductory chapter, outlines the background information on the topic and offers the research problem, objective, and rationale. The following chapter, Chapter 2, highlights the related literature on the topic. Chapter 3 will focus on the research approach, design and address the data

collection and analysis process. Chapter 4 will present the findings from the interviews as well as the discussion of these findings. Finally, chapter 5 will provide recommendations, reflections as well as the conclusion.

2. Chapter 2: Literature review

2.1 Introduction

This chapter compiles an overview of pertinent studies on implementing LSS in improving operational performance in different manufacturing sectors. The drive is to incorporate the data from different manufacturing sectors to enhance the LSS application in the train manufacturing sector. From the various studies reviewed on LSS, four concepts will be discussed. Firstly, productivity with regards to factors that affecting LSS and the application of it. Secondly efficiency in its relation to productivity and the application of LSS to it. Thirdly lean, six sigma and LSS will be discussed. This will be followed by a discussion on the factors essential for sustaining six sigma implementations in rail manufacturing. This chapter will then outline (Schmenner & Swink, 1998) (Schmenner & Swink, 1998) (Society Insurance, 2021) (Schmenner & Swink, 1998; Creswell, 1998) the theoretical framework before concluding.

2.2 Productivity

Productivity is typically referred to as a ratio, used to measure performance. Productivity is the ratio between outputs and inputs (Coelli, 2005). Improving productivity involves eliminating non-value-added activities, reducing waste, and enhancing customer satisfaction (Anh, 2023). The talk is about the reduction of waste and the increase in output.

Productivity in any organisation depends on various elements (Coelli, 2005). These elements are internal and external (Niu et al. 2023). Internal factors include workplace culture, physical environment, material shortages, equipment availability, human resource topics, and process complexity (Sreekumar et al., 2018). External factors include other transport modes, competition, political will and economic development (Niu et al., 2023). A key challenge for businesses is identifying what negatively impacts productivity and taking corrective actions to enhance efficiency and profitability. Common productivity measures include output per worker or actual vs. expected task completion times (Sreekumar et al., 2018). This study seeks to examine how the application of LSS methodologies improves productivity by minimizing resource waste and eliminating defects in processes/products.

2.3 Efficiency

While productivity is mainly about making more products, efficiency is about doing the work in the best way possible. Being efficient means getting the job done without wasting materials, time, or energy. Efficiency is often shown as a percentage, with 100% meaning everything is done perfectly, products are made at the lowest cost without losing quality, assuming all other factors remain unchanged (Gehringer, 2022).

A study by Sharma et al. (2020) conducted in an Indian auto parts manufacturing company to address efficiency, productivity and quality issues. LSS approach was used, combining DMAIC methodology with tools like 5S, Kanban, brainstorming, cause-effect diagrams, and Pareto charts. A value stream map helped identify areas of improvement. The implementation reduced defects by 53%, improved the Sigma level from 3.78 to 3.89, and lowered defects per million opportunities (DPMO) from 11,244 to 8,493. The study identified and reduced wastes, improved productivity, and resource utilization while maintaining quality standards. Overall, this approach improved the plant Efficiency (Sharma et al., 2020).

Table 1: Results comparison before and after implementation of LSS framework

S.No	Parameters	Before	After	Percentage change
1	Defective pieces at leakage test station	64	30	−53
2	Raw material batch size	200	300	50
3	Idle time at bottleneck	36.75%	6.71%	−30.04
4	Sigma level	3.78	3.89	2.91
5	DPMO	11,244	8493	−24.46

Source: (Sharma et al., 2020)

The business environment has changed significantly, becoming more competitive and challenging (Raman, 2019). The changes are attributed to having more competitors and the customers demanding quicker deliveries of goods with competitive cost, high quality and environmentally friendly products. In this context, organisations seek to enhance their operations and boost productivity and efficiency by implementing LSS, a data-driven methodology (Bagherian, 2024). Increased competition in the global industrial sector prompts businesses to select effective strategies. Delivering high-quality products and services is one way to maintain a competitive edge (Raman, 2019).

2.4 Lean, Six Sigma and Lean Six Sigma

Lean is a method that focuses on removing waste and making processes simpler. When paired with Six Sigma, it becomes LSS, a strong approach that improves the use of resources (like people, materials, and money) while ensuring products are delivered on time. Six Sigma adds a focus on quality and uses statistical tools to monitor processes, aiming to reduce mistakes and make processes more consistent. Together, LSS create a system that boosts efficiency, productivity and keeps quality high (Ghaleb, 2020). Figure 2 bellow, illustrates the tools used between LSS and also indicates the common tools between the two concepts.

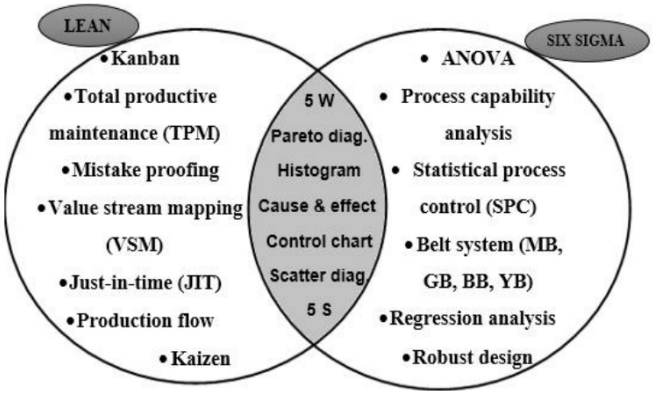

Figure 2 Common Tools of lean and six sigma Source (Ghaleb, 2020).

2.5 Lean

Lean is a comprehensive approach that integrates various management practices. Its central aim is for these practices to work together in synergy, creating an efficient, high-quality system that delivers products at the pace of customer demand with minimal or no waste (Shah, 2022). Its origins can be dated back to the transition between craft production and mass production in the 1930s (Mikel & Harry, 1994) (Womack, Jones, & Roos, 2007)). Lean management utilizes several key processes including Value Stream Mapping, Standardization, Continuous Improvement, Flow Optimization, Just-in-Time systems, and Visual Management. Organisations needs to continuously identify ways to improve their processes and operations, this is known as Kaizen. The term, originating from Japan, means "improvement," and it has been widely adopted worldwide, influencing continuous improvement standards such as ISO 9001:2015 (Ghaleb, 2020).

These interconnected methods collectively enhance an organisation's operational efficiency and performance (Ghaleb, 2020). Schonberger (1982) and White et al. (1999) stated that the most frequently mentioned benefits of lean practices include increased labour productivity and quality, as well as reductions in customer lead time, cycle time, and manufacturing costs (Shah, 2022).

2.6 Six Sigma

The Six Sigma methodology significantly reduces variations and defects in manufacturing processes, which are impacted by the 4M 1E factors: Man, Material, Method, Machinery, and Environment (Trimarjoko, 2022). According to researchers Zu et al. (2008), Six Sigma (SS) falls under the category of operational improvement programs focused on enhancing the quality or reducing variability in process outcomes (Swink, 2012). Since its inception in the mid-1980s, the Six Sigma process improvement program has gained widespread adoption. Mikel and Harry (1994) noted that six-sigma extends beyond quality control but it is more a business strategy methodology. A report by Nakhai and Neves (2009) indicates that many Fortune 500 companies have implemented Six Sigma (Swink, 2012).

Breyfogle (2003) emphasized that Six Sigma stands apart from other process improvement programs due to its unique focus on being entirely customer-driven and data-based (Swink, 2012). According to researchers (Blakeslee, 1999; Hahn et al., 1999; Harry & Schroeder, 2000; Braunscheidel et al., 2011), Six Sigma is characterized as a data-driven problem-solving method, a business process, a disciplined statistical approach, and a comprehensive management strategy (Swink, 2012). There is also a methodology within SS called Design for Six sigma (DFSS), this methodology focuses on the design phase of products or processes ensuring that they meet customer requirements (Arcidiacono, 2024). Six Sigma, with its systematic and structured approach known as DMAIC, has been demonstrated to effectively identify, measure, analyse, and control processes (Trimarjoko, 2022).

2.6.1 DMAIC (Define, Measure, Analyse, Improve, Control)

The DMAIC process is the methodology used in Six Sigma to enhance an existing process (Ghaleb, 2020). Numerous studies on Six Sigma implementation have demonstrated that the DMAIC methodology can address various challenges faced by manufacturing and service industries. These include reducing product variation and defects, lowering production costs, decreasing error rates,

reducing complaints, increasing productivity and equipment lifespan, enhancing customer satisfaction, improving performance, and boosting business profits (Trimarjoko, 2022).

Continuous improvement efforts are extensively implemented using the DMAIC cycle (Define, Measure, Analyse, Improve, and Control) within the LSS framework (Anh, 2023). Figure 3 shows an easy-to-follow version of the Six Sigma DMAIC method, with clear steps on how to use lean tools in each stage. This approach uses data and a structured process to find areas for improvement and analyse problems (Ghaleb et al., 2017).

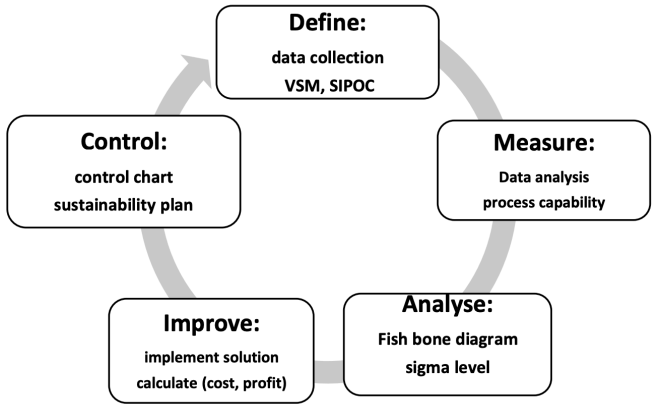

Figure 3: Lean Six Sigma implementations phases. Source: (Ghaleb et al., 2017).

2.7 Factors essential for sustaining Six Sigma implementation in rail manufacturing

Factors essential for sustaining Six Sigma implementation include (a) The competence of Belt System employees, who play a crucial role in possessing the necessary knowledge and skills to effectively apply Six Sigma tools and methodologies (Bagherian, 2023); (b) Project management skills, which are vital for improving the efficiency and success of Six Sigma initiatives by providing a structured approach with clear objectives, optimal resource use, risk management, stakeholder engagement, and effective monitoring and control; (c) Organisational, economic capability, where sufficient resources are allocated to ensure long-term sustainability (Bagherian, 2023); and (d) Leadership commitment and engagement, where leaders must demonstrate strong dedication to Six Sigma, align it with organisational goals, and cultivate a culture of continuous improvement (Bagherian, 2023).

2.8 Theoretical framework

The theory used for this research is the Swift, Even Flow theory as developed by Schemenner and Swink (1998). Over-time this theory has been refined by various scholars (Devaraj et al., 2013; Onofrei, 2020; Schmenner (2012). Schmenner (2012) and Devaraj et al. (2013) suggested that swift even flow has emerged as a foundational theory supporting manufacturing strategy, offering a comprehensive perspective on operational capabilities. The theory emphasizes accelerating the flow of materials through the factory by minimizing variability in quality, quantities, or timing (Onofrei, 2020).

The main tenets of this theory are variability, bottlenecks, scientific methods, quality and factory focus. Variability focuses on how variability affects outputs, an increase in variability can be random or planned. This theory holds that decreased variability increases productivity thus, the standardization of processes as well as consumption patterns and job complexity is pertinent to productivity. Through focusing on bottlenecks, the swift even flow theory asserts that the elimination and management of bottlenecks improves productivity. Bottlenecks are constraints that decrease productivity i.e., breakdowns, quality problems, worker absenteeism etc.

The third tenet of this theory is scientific methods and states that productivity can be improved by applying scientific methods. The scientific methods employed include statistical analysis which identify non-value-added work that impact productivity. The fourth tenet is quality and states that quality problems decrease productivity thus managing the process flow can improve quality and increase productivity. The fifth tenant is factory focus and states that the smaller number of products/processes the more productive a given factory will be.

The LSS and Swift, Even Flow theory is aligned as they both seek to improve productivity by reducing waste. Given the aim of this study wherein we are assessing how the application of LSS principles improve efficiency and productivity in the train manufacturing industry, this theory addresses issues related to efficiency and productivity thus its consideration.

2.9 Literature review conclusion

Research has highlighted a shared understanding of LSS among various scholars. This consensus revolves around its effectiveness in enhancing productivity in the manufacturing industry. The theory of swift, even flow, was most appropriate for this study. This demonstrates the suitability of LSS principles in addressing productivity challenges in the rail manufacturing sector. The productivity issues in rail manufacturing, particularly regarding train deliveries by Gibela and Bombardier, were identified by two researchers (Venter, 2021) and (Reuters, 2019).

3. Chapter 3: Research methodology

3.1 Introduction

Chapter three details the methodology employed in this research. This will include a discussion of the research instruments, data collection methods, limitations, measures to ensure the quality of this research as well as ethical considerations.

3.2 Research design

The research is of a qualitative design, this method is interpretive, focusing on the processes or developmental patterns instead of only the final products or outcomes (Nassaji, 2020). Qualitative research assumes that reality is constructed, multidimensional, and constantly evolving. It involves interpreting different perceptions of reality (Merriam, 1995). Thus, the use of the qualitative design as we are looking at productivity and efficiency from the experience of the various LSS experts. Qualitative design is best suited to meeting the research objectives as they are of an explorative nature wherein each participant will speak to their use of LSS. Creswell (2017) agrees, explaining that qualitative research helps to deeply understand people's experiences, and lets participants share their views openly.

3.3 Data collection methods

3.3.1 Population

The Population will include experienced and qualified individuals working in rail manufacturing space.

3.3.2 Sample and sampling method

A purposive sampling was used for the research. This sampling method is a convenient sampling method in which the researcher decides on the study sample. The study population is specialised hence the

suitability of this approach. The focus will be on LSS and productivity in the manufacturing sector. In purposive sampling, the population or resources used have some special significance (Mweshi, 2020). The interviews will focus on LSS qualified people in rail manufacturing space. The number of interviews will amount to 11, this is in line with Creswell's (1998) recommendation five and twenty-five interviews for a qualitative study. Through conducting this number of interviews, we have established patterns and reached a point of data-saturation wherein there were no new insights discovered from participant 9 onwards (Guest et al., 2006).

3.4 Research instrument

Structured interviews were the research instrument. A structured interview follows a set format where all candidates are asked the same predetermined questions in the same order. This ensures that each interview is consistent and allows for a fair, unbiased assessment of the candidates' responses (George, 2022).

3.5 Data analysis strategies and interpretation

Thematic analysis approach as suggested by (Braun & Clarke, 2023) was followed in the data analysis. They suggest that thematic analysis is a theoretically flexible approach that allows for the detailed identification, description, and interpretation of patterns (themes) within a data set (Dawadi, 2020). The process followed was;

1. Reading and re-reading the interview text while making notes
2. Identifying codes and patterns within the codes
3. Identifying emergent themes from the codes
4. Clustering related themes and writing up

3.6 Quality assurance

3.6.1Transferability

This research is transferable as it focuses on enhancing productivity in a manufacturing environment using LSS. The knowledge and fundamental principles of productivity improvement can be applied to any other manufacturing organisation in addition, LSS can enhance the knowledge of the organisation's

management by offering insights and highlighting relevant issues to consider when implementing LSS in various contexts, enabling managers to make more informed decisions (Juliani, 2019).

3.6.2 Credibility

This research is offering an interpretation of existing data to derive a particular understanding added with the views and understanding from experienced and qualified individuals using interviews. This research is therefore credible from interviewing experienced and qualified individuals.

3.6.3 Reliability (or dependability)

The research will adhere to member check or peer validation method to ensure reliability. This will be achieved by having the supervisor or the school research committee review the research. This approach will ensure the reliability of the research.

3.7 Ethical considerations

To ensure no harm to the participants of this study, informed consent was upheld, the participants' identity was protected, participation was voluntary and explained fully and confidentiality has been guaranteed.

3.7.1 Informed Consent

The participants of this study were informed of the nature of this study before the interview process. Participation was voluntary and the participation did not advantage or disadvantage the participants in any way. Participants could withdraw from the study at any point without penalty.

3.7.2 Confidentiality

Participant's confidentiality was upheld through the use of pseudonyms in the presentation of the results of this study. At no point in this study did they provide any personally identifying information. The only persons to gain access to the transcripts from the interviews are the researcher and their supervisor. The transcripts will be stored for 5 years until they are destroyed.

3.7.3 Anticipated harm to the participants

It is not anticipated that participation in this study would harm the participants physically, psychologically or in any way.

4 Chapter 4: Research findings and discussions

This chapter will present the findings from interviews conducted and later discuss those findings. The participants of this study underwent a structured interview in which they were asked questions to assess how the application of LSS principles improve efficiency and productivity in the train manufacturing industry. Eleven experienced and qualified individuals working in rail manufacturing space were interviewed. From these interviews, three super-ordinate themes and nine sub-ordinate themes were identified. The participants also provided a roadmap to implement LSS in the rail manufacturing industry based on their knowledge and experience. This roadmap will be presented as a figure.

4.1 Interview participants

A description of each participant is tabulated below;

Table 2*:* Interview Participants

Participants	Position	Work experience (Years)	LSS Belt
Participant 1	CI site leader	10	Green
Participant 2	Production manager	14	Black
Participant 3	Head of quality	30	Green
Participant 4	Head of supply quality for the region	24	Black
Participant 5	Site industrial quality manager	15	Green
Participant 6	Senior supplier development manager	24	Green
Participant 7	Senior Production Manager	10	Yellow
Participant 8	Process engineering manager	10	Green
Participant 9	Industrial quality manager at final	19	Green
Participant 10	Industrial quality Manager	8	Black
Participant 11	Participation unit quality manager	23	Green

4.1.1 Lean six sigma belts

An article by Laureani and Antony (2012) discussed the different coloured LSS belts. The belts show increasing levels of knowledge and responsibility in LSS:

White Belt: The starting level that requires about 40 hours of training. People with White Belts help with small improvement projects in their immediate work area while learning the fundamentals.

Yellow Belt: Team members who understand the basics and they help with gathering information for projects. They contribute while still doing their normal daily work responsibilities.

Green Belt: These practitioners complete roughly 80 hours of training to lead part-time improvement projects, usually within one department. They apply many advanced techniques similar to Black Belts.

Black Belt: Highly trained experts with 160 hours of instruction. This people manage major projects fulltime. They use sophisticated analysis methods to create substantial financial benefits.

Master Black Belt: The top certification for proven Black Belts. This people can train others and shape how the entire company uses LSS. They coach Green and Black Belts while guiding the organization's improvement strategy.

4.2 Themes identified

The superordinate and subordinate themes that emerged from the interviews are presented in table 3 below. The themes identified address the first two objectives of this study. The first theme (productivity and efficiency) as well as the second theme (leadership and organisational culture) explore the challenges of productivity and efficiency which is the first objective. The second objective is addressed by the third theme (Lean six-sigma) wherein the manner in which the implementation of LSS enhances productivity and efficiency in train manufacturing is discussed.

Table 3: Themes

Superordinate themes	Subordinate themes
Productivity and efficiency	Variability Standardization Waste
Leadership and organisational culture	Provision of support Empowerment/Disempowerment Alignment
Lean six-sigma	How lean six-sigma improves efficiency and productivity Challenges encountered Effective tools of lean six sigma

Each of the themes identified speak to the objectives of the study and will thus be presented in this order. The first two themes (productivity and efficiency as well as leadership and organisational) culture address the first objective which is to explore challenges of productivity and efficiency in the rail manufacturing industry.

4.2.1 Productivity and efficiency

Productivity and efficiency were spoken about with regards to the challenges that are being encountered. The challenges to productivity and efficiency were explained in terms of variability, standardization and waste.

4.2.1.1 Variability.

When explaining the challenges facing productivity and efficiency within their work, the participants explained how variability poses a challenge to productivity and efficiency. This was explained in terms of variability in human and material resources as well as variability in process. In train manufacturing variability has been found to result in poor quality, low productivity which impacts company deliverables to customer's needs. The quotes below explain**;**

I believe it is variability and variability caused by processes that's not well defined. Processes that are not well followed. So, you can, even if it is defined, you can have a closely defined but then it's not well followed because it has not been practicalized for the use of the operator, another thing that hinders or that cause variation. It is poor adherence to standards, and all of these contribute to variability that ultimately results in poor quality, poor productivity, poor utilization of employees. It even impacts on safety in the work environment. – Participant 1

Changes in environment, changes in people, your resources. So, when you have a high turnover of people, you will find that the sustainability of the skill level is not quite there, and this is what also leads to quality defects. So, in terms of ensuring that we have good continuity, in terms of business, it also resides in the same place. – Participant 3

It will be a poor quality. It will be missing parts. It will be breakdown of machines at most. – Participant 5

I think the main factors one would be the movements, like people move a lot when they are within the process, especially for the excess of equipment to assist with their activities. – Participant 9

4.2.1.2 Standardization.

Standardization in particular, the lack thereof was alluded to as a challenge to productivity and efficiency. It was noted that the lack thereof as well as the lack of adhering to standards affected productivity and efficiency negatively. The following was shared;

Processes that are not well followed. So, you can, even if it is defined, you can have a closely defined but then it's not well followed because it has not been practicalized for the use of the operator, another thing that hinders or that cause variation. It is poor adherence to standards. – Participant 1

In production, there are some people who find ways of doing things, and then they don't follow the process accordingly. Then in the process, they end up delaying. – Participant 9

4.2.1.3 Waste.

Another aspect that hinders productivity and efficiency as explained by the participants is waste. It was explained as follows;

> *It's the seven wastes. One of the biggest things that hinders, it's the presence of the seven waste which include, for example, over production, which include inventory, when we have got a lot of inventory waiting, you know that some of them that hinders production from progressing properly. – Participant 2*

> *It could be different aspects of waste, waste in the way, maybe the process is designed initially, waste due to inferior materials, waste in terms of time or idle time, and waste in terms of cost of non-quality could be scrap, could be customer complaints, but the main foundation is waste. – Participant 4*

> *It's the waste, but I know the term waste can be defined as various different items, so that's part of what I'm doing here as well in the department that I'm in, to understand all the unnecessary activities or the unnecessary documentation. Because the department that I'm in as well, the employees tend to be bogged down by the number of paperwork that needs to get done, and everything needs a specific template, a specific signature. – Participant 6*

4.2.2 Leadership and organisational culture

All participants explained the impact of leadership and organisational culture on the everyday practices as well as sentiments held by employees about their workplace. This was expressed in terms of provision of support empowerment or disempowerment and alignment.

4.2.2.1 Provision of support.

Provision of support by leadership was expressed as a critical component to the success of projects as well as providing direction. The following are how this sentiment was expressed;

> *Very important from a leadership point of view. It sets the tone. It sets the direction. Without leadership, the tone, the direction is just not there. – Participant 3*

Even if you are running a Lean Six Sigma project without support from leadership, it will be difficult, because, firstly, people will not honour that the project team meetings, people will not adapt to change. – Participant 4

The leadership have a responsibility to ensure that the people are trained, qualified, competent. They have got the role to ensure that the material is available at any given time. They've got a role of ensuring that the methods the processes are defined well for people to achieve. They've got a role of supporting the team in terms of providing and maintaining the right machine that will be able to execute productivity. They need to provide a conducive environment when they both the team to be productive. – Participant 5

4.2.2.2 Empowerment/Disempowerment.

The manner in which leader and organisational culture can empower or disempower employees was discussed by the participants of this study as follows;

What I can say is that a bad culture whereby employees don't feel safe, they don't feel they have got they can make that decision. They you know, a bad culture can, can make organisation to, let's say, to be poor, you know, in terms of executing whatever that they want to achieve in their production of the whole company organisation. – Participant 2

So, it's important that employees are constantly engaged to know. What's happening in the business. When they know what's happening in the business, they understand a little bit better as to what they are doing and the bigger picture. Of their contributions to it. Should an employee not know it becomes difficult, because all they're doing is they're coming to just execute like, it's almost robotic. –Participant 3

Employee engagement makes employee hooked up or they're engaged. What it does. It encourages them. They feel part of the company. They feel valued. They feel that their input into the business is recognized. Engagements provide a platform where management give update, also employees to raise questions and get feedback, and in that that alone ensures that the employees feel valued, feel recognized, feel part of this train. And once they feel that

way, it changes the whole dynamic, 360, so you see people being engaged in what they do. – Participant 5

So, if employees are not motivated, they don't really, they won't really contribute much to achieving the end goal. They'll just do the bare minimum. So, you need employees to be motivated and understand that we're working towards the same goal. They need to feel like they're part of the of us achieving the end result. – Participant 8

4.2.2.3 Alignment.

Having the same understanding of work and how a project should progress was highlighted as an important factor in achieving success in a given project. Participants explained how leadership contributes to this below;

It's also very important that leadership understands what happens on the ground, because that understanding of what happens on the ground will allow you to strategize in the right way, to get the right output from the people – Participant 3

So, culture is a key element in the manufacturing process, because it defines and it directs how the vision and the mission of the business needs to be well cascaded to all individuals, the types of values that the business has defines how the culture of the business and the operators will be to achieve the output required. Culture also hinders, especially if you don't have a good Stakeholder Relations and create uncertainty in the organisation. – Participant 7

Well, employee engagement is critical to any organisation. If you don't have employee engagement, you will be out of touch with what is actually happening on the floor. You will not have a feeling of the current morale on the floor, or even some sort of indication or end of any possible interferences, morale issues, supply chain issues that you might or may be unaware of. – Participant 11

The second objective that this study pursued was to illustrate how the implementation of LSS enhances productivity and efficiency in train manufacturing. The theme identified in this regard was LSS which comprised of three sub-themes.

4.2.3 Lean six-sigma

Participants discussed lean six-sigma in terms of how it improves efficiency and productivity, the challenges encountered when implementing lean six-sigma and the tools they found effective.

4.2.3.1 How lean six-sigma improves efficiency and productivity

All participants were experts in lean six-sigma in varying degrees. They expressed how lean six-sigma improves efficiency and productivity as follows;

> *Lean Six Sigma deals with the waste in the process, whereas the Six Sigma deal with variation in the process. – Participant 5*

> *Lean Six Sigma is used to reduce waste where it could be waste, in terms of the tact time, or the delivery, or even the reduction of defects, anything that is costing, the cost the company, delaying the process or taking longer so lean six might help us to reduce those times, or to reduce the defects, to improve effectivity, actually, okay, all right. – Participant 9*

> *Lean has helped us, like for example, we've got a system that we use. This has helped us define, like the basic of operational stability that you need to have SIPOC or so that you can understand your inputs and outputs, your processes due to your 5s and need to have standardized work. –Participant 10*
>
> *Lean Six Sigma is 360 degrees developed system, I think, by Motorola in the early years. It works on a principle of DMAIC now, the DMAIC principle works on a basis of define, measure, action, implement and control the critical path for Lean Six Sigma, and what they focus quite a lot on is defining your actual project, measuring very accurately, then analysing that data to ensure that the data quality is good and eliminating inefficiencies in the data quality, putting a plan together to implement the improvements appropriately, and then also hosting a plan to control the measures that's been implemented. – Participant 11*

4.2.3.2 Challenges encountered.

Participants expressed the challenges they encountered when implementing lean six-sigma as follows;

> *The two major things, the firstly is time. No one has time. And also, when there's an issue that an organisation is facing, we want results tomorrow, and Lean Six Sigma is not a approach*

to be rushed, okay, you need to invest time, and as a result, time is always a constraint. The second topic is linked to time. It's people availability – Participant 4

People just don't want to do things differently. They don't want to do things out of their norm. – Participant 6

Okay, the most challenges that I encountered is, if you don't describe the problem clearly, you won't be able to sort it at the end. Data Collection, mostly, it's also problematic because in most cases, we get data that is not 100% accurate, so you need to be able to clean the data that you have to get the required output, or to be able to analyse it correctly. – Participant 8

The buy in from the stakeholders. When you present, you do all the presentation, but it depends on all the stakeholders if they are buying in in what you're saying, some of them, they will buy in. – Participant 9

4.2.3.3 Effective tools of lean six sigma.

In their experience with lean six-sigma, the participants mentioned the following as effective tools;

Okay, so for solving productivity issue, the Lean Six Sigma tool that is efficient at Value Stream Mapping, because through value stream mapping, you are able easily, you can easily identify your bottlenecks, process capability. When you're implementing a new process or even an existing process, you need to be able to determine if your process is capable of achieving the required output, whether it's quality or the cycle time. –Participant 8

So, let's say one of the Lean Six Sigma two that I found to be effective, it's JIT. One can look at JIT. It's Just in Time, we have got part of our parts in our process, which are delivered right in time. This means it's effective, because there is no movement of parts from our main warehouse to the line. – Participant 5

I think in our environment, sometimes a simple thing, like doing a value stream mapping has helped us reduced. I mean, every time we do a value stream, we achieve more than 10% of productivity and then we also use the DMAIC approach if we want to improve something – Participant 10

The last objective is presented as a theme wherein participants expressed how LSS should be implemented in a rail manufacturing organisation.

4.3 Roadmap to implement LSS in the rail manufacturing organisation

Participants of this study offered a roadmap to implement LSS in the manufacturing organisation thus addressing the third and objective of this study. Their approach was informed by their knowledge and experience with LSS particularly DMAIC. They suggested a four-layered approach starting off by problem conceptualisation/identification and then preparation followed by execution and finally sustainment. Each layer of this approach was characterized by a given action. In the problem identification/conceptualisation stage observations, brainstorming, and problem definition and prioritization takes place. In preparation there is an alignment of all stakeholders on goals and a definition of governance. Execution includes leadership support and resource commitment. Sustainment speaks to regular controls/monitoring as well as continuous improvement The figure below annotates this approach;

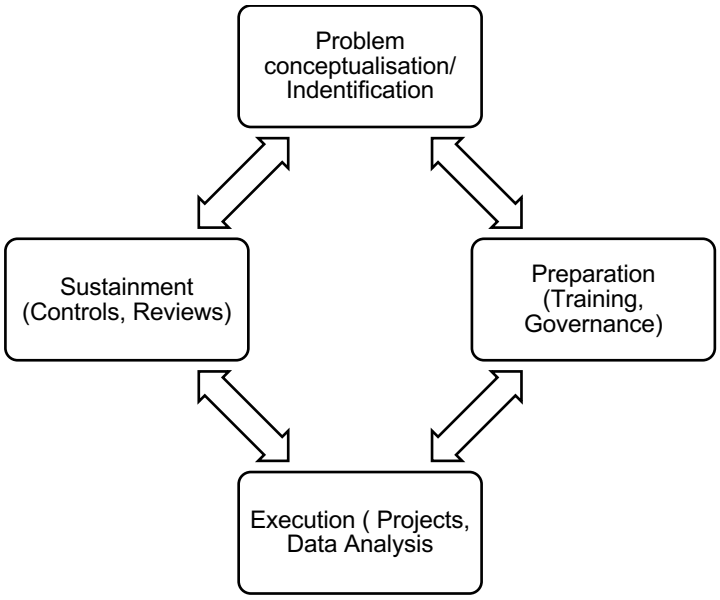

Figure 4: Roadmap to implementation of LSS in rail manufacturing

The above are the findings from the structured interviews conducted of eleven participants. Three superordinate themes with nine subordinate themes derived from the information gathered. A roadmap for the implementation of LSS in a rail manufacturing organisation was also offered based on the inputs from the participants. The next part of this chapter will be to a discussion these findings.

4.4. Discussions of findings

4.4.1. Productivity and Efficiency

The study shows that productivity and efficiency in the rail manufacturing sector, are negatively affected by variability, lack of clear procedures, and waste. These results into poor product quality, poor delivery to customers and generally not meeting the customer's needs.

From the interviews a number of participants mentioned variability as one of the key problems particularly as it relates to issues with staffing, materials, and processes. This may be due to frequent employee turnover which creates skill shortages, and unclear procedures leading to mistakes and equipment failures. One of the ways in which LSS has been found effective has been through minimizing variability (Trimarkoko 2022; Zu et al, 2008). Variability can be found throughout the manufacturing process with regards to 4M 1E factors (Man, Material, Method, Machinery and Environment) (Zu et al, 2008) and this has been the finding of this study. Variability and productivity are inversely related, and it is also inversely related to efficiency (Onofrei, 2020). The findings of this study have confirmed that when variability is high productivity and efficiency tend to be low. As such reducing variation creates a stable and reliable operations (Trimarjoko, 2022).

Another major concern gathered from the interviews was the lack of standardization. This is more prevalent when procedures are in place, they are often not followed properly, causing delays and inefficiencies (Ghaleb, 2020).

Waste was also identified as a key issue affecting productivity. Participants pointed to waste such as making too much product, storing extra materials, downtime, and doing unnecessary paperwork. These concerns reflect LSS's goal of cutting out waste to make processes more efficient and cost-effective. Literature also agrees that LSS approach helps organisations eliminate waste, enhance quality, and reduce defects or inconsistencies in their processes (Ishak, 2020).

4.4.2 Leadership and Organisational Culture

The study found that leadership and the overall workplace culture have a strong impact on how engaged employees are, how well processes are followed, and how successful operations are. Literature also indicated that culture has an impact to productivity and efficiency. Culture being one of the internal factors impacting productivity and efficiency (Bagherian et al, 2025). The participants mentioned the

following empirical archiving high productivity or efficiency; support from leadership, employee empowerment, and alignment between strategy and daily work.

Support from Leadership: Participants in different ways stressed that leadership needs to set a clear direction, provide necessary resources, and make sure processes are followed. Strong leadership is essential in the successful implementation of LSS, in the absence of strong leadership you often face push back and lack accountability (Bagherian, 2023; Gomaa, 2025).

Empowerment and Disempowerment: Participants mentioned that disengaged workplace culture leads to poor decisions and employees doing tasks without thinking critically. The inverse of this is what literature supports, when employees feel involved and valued, they are more motivated, creative, and take ownership of their work, which boosts productivity. LSS literature agrees that people play a huge role in its success (Ghaleb, 2020).

Alignment: Leaders need to understand day-to-day operations in order to connect the company's goals with actual work on the ground. When leadership and staff are not aligned, it leads to inefficiencies. A common vision and clear communication help teams work better together.

4.4.3 Lean Six-Sigma (LSS)

LSS experts emphasized its value in improving operational performance by systematically cutting waste and reducing process variation using structured methods like DMAIC (Define, Measure, Analyze, Improve, Control) (Trimarjoko, 2022). Tools such as Value Stream Mapping (VSM) were recognized for exposing process bottlenecks, while Just-in-Time (JIT) helped reduce excess inventory and improve workflow efficiency. Process capability analysis was also noted for helping maintain consistent quality (Bhat, 2019). Together, these methods not only boost productivity and efficiency but also encourage a culture of continuous improvement driven by data rather than assumptions.

Despite its advantages, implementing LSS comes with challenges. Participants pointed out that organisations often want quick outcomes, while LSS requires detailed analysis and long-term commitment. Resistance to change from employees that are used to traditional practices, inaccurate data, and a lack of support from leadership and other stakeholders were also major obstacles. However, when

using correct tools like DMAIC, VSM, and JIT are highly effective in driving efficiency, lowering costs, and creating more stable processes (Bhat, 2019).

4.4.4 Roadmap to Implement LSS in the Rail Manufacturing Organisation

Participants stressed the need for a well-organized approach to implementing LSS in the rail manufacturing industry, starting with thorough training and skill development. The company should build internal capability by developing Green Belt and Black Belt professionals who can lead continuous improvement efforts. Laureani and Antony (2012) also discussed the impotency of the belt system for LSS. This training phase is vital to creating a solid foundation for sustaining LSS over the long term. Strong leadership support is also crucial in ensuring that there is required resources. Regular monthly review meetings were seen as important for monitoring progress, holding teams accountable, and quickly resolving issues to keep projects aligned with business objectives.

It is also important for the organisation to understand and evaluate their current performance to identify problem areas. Thereafter to develop clear goals through detailed project charters to guide their efforts. Literature also mentions the DMAIC (Define, Measure, Analyze, Improve, Control) methodology as the core framework for improving processes using data-driven strategies (Trimarjoko, 2022). This approach helps the organisation eliminate inefficiencies, cut waste, and boost productivity ultimately leading to sustained operational improvements through LSS.

4.5. Conclusion

Both literature and expert interviews show that LSS is vital for improving productivity and efficiency in rail manufacturing. Key operational challenges such as inconsistent processes, missing standards, and wasted time or materials can impact performance. LSS fixes these issues using proven methods like DMAIC (a step-by-step improvement process), Value Stream Mapping (which spots inefficiencies), and Just-In-Time (which reduces excess inventory). These tools help make processes more reliable, reduce unnecessary steps, and improve quality.

However, LSS tools alone are not enough for success. The study found that good leadership, involved workers, and a culture of constant improvement are equally important. Leaders of the organisation need to support changes, provide training or resources, and encourage employees to suggest improvements.

The organisations should also be prepared to manage unexpected problems that could disrupt LSS implementation progress. It is of high importance to strike a balance between the following three elements: people, processes, and performance tracking. When these elements work together, rail manufacturers can get the most from LSS and keep improving their efficiency and productivity, in turn delivering to the customer's needs.

5 Chapter 5: Recommendations and conclusions

The challenges that objective one sought to explore pertaining to productivity and efficiency in the train manufacturing industry were identified by the experts as variability, leadership and organizational culture, waste and a lack of standardization. In illustrating how the implementation of LSS enhances train manufacturing productivity and efficiency as pursued by objective two, the experts noted that LSS provides a framework for problem solving such as VSM, PDCA and QRQC etc. They stated that through the support and drive from leadership LSS can be implemented effectively wherein a culture of LSS is ingrained in the organization. Objective three was met by creating a roadmap for effectively implementing LSS to improve productivity in the train manufacturing space. The experts stated that following the DMAIC process is the best way to create a roadmap of implementing LSS in the train manufacturing industry. They suggested a four-layered approach starting off by problem conceptualisation/identification and then preparation followed by execution and finally sustainment which is denoted in Fig 4.

The introductory chapter of this study outlined the South African train manufacturing industry and the necessity of this study. Current literature related to LSS, productivity, efficiency and the theory of swift even flow were discussed in chapter 2. The qualitative research method as used by the researcher has been outlined in chapter 3. The findings presented in chapter 4 indicated the elements that affect productivity and efficiency and the role of leadership and organisational culture. Lean Six Sigma was found to be an effective tool in addressing productivity and efficiency challenges in the train manufacturing industry. This chapter is a presentation of the recommendations, researcher reflections and the conclusion to this study. The recommendations will be presented two-fold, firstly general recommendations will be made in relation to this study's objectives and secondly recommendations for future research will be made. The researchers' reflections in terms of their experience throughout the research process will be shared and finally the study will conclude.

5.1 Recommendations

5.1.1 General recommendations

5.1.1.1Productivity and Efficiency

This study sought to address the challenge of productivity and efficiency in the rail manufacturing industry where trains were not delivered timeously and had quality concerns. The study indicated that inconsistency and poorly organised processes are a major input of inefficiency. The recommendation is for organisations to establish clear Standard Operating Procedures (SOPs) and enforce compliance of everyone. Implement Lean tools like 5S and Value Stream Mapping, this can help visualize and simplify workflows. Additionally, the research highlighted significant waste problems including overproduction and idle time. It is also recommended that organizations should constantly audit their operations to identify waste, and digitize manual processes to eliminate unnecessary tasks. These practically improves utilisation of resources in manufacturing.

5.1.1.2 Leadership and Organisational Culture

The study showed that employee turnover and skill shortages have a negative impact on operational efficiency. The recommendation is for organisations to implement a complete LSS training program with different certification levels to build employee skills and also retain them. It is also paramount for organizations to keep all employees involved by having suggestion boxes, fostering a continuous improvement culture. The other recommendation is for leaders to continuously visit work areas to understand challenges, align improvement projects with company goals, and provide necessary support to everyone. The combination of proper training, communication, and strong leadership, can create a highly efficient team. These practical steps create a win-win situation where employees grow their skills while the organization improves its performance.

5.1.1.3 LSS and Roadmap:

The study further established that in order to have a roadmap of implementing LSS is quite challenging. The recommendation is for organizations to use the DMAIC method. This step-by-step process helps identify problems using real time data, to make informed decisions. Once changes are made, they should be maintained. To keep progress on track, companies should hold monthly review meetings, to monitor key performance indicators (KPIs), and take quick informed action when issues come up. By utilising

this structured approach with regular performance checks, organizations can continuously improve and achieve long-term success.

5.1.2 Recommendations for future research

It is recommended that the future studies not only interview the experts but also include the operational stuff. This is to also get their first-hand inputs on LSS and its impact to their day-to-day activities. The other recommendation is to make the interviews semi structured, to get more information from participants that may be nervous or need more time to settle into the interview. The last recommendations are that the interviews should be held outside work-hours where the participants are more relaxed and have enough time to engage.

5.2 General reflection

This study is closely related to my passion and the work I do every day. I am quite familiar with concepts used as well as what is being practiced. This closeness to the work has meant that there are certain aspects of my work that I overlook as they have become a second nature such that I am unable to articulate them. Having my supervisor as an external expert has allowed me to counter this shortcoming through highlighting my blind-spots. I chose the qualitative research method as it was best suited to answering the research question wherein the interest was in the experiences of various LSS experts. I found it quite challenging to analyse the interview material as I am used to numerical data and not text. I also realized that, as an interviewer with a significant position in the rail industry, some interviewees seemed to hold back their views.

I think a semi-structured interview might have encouraged them to open up more and provided deeper insights. Before the interviews, I made sure to encourage participants to relax and share their knowledge, assuring them that there were no wrong answers. I also found that my understanding of LSS was challenged and expanded by the responses I gathered. Overall, this process has been challenging, but I'm very grateful to all the participants. I hope my presentation of the research findings and discussions accurately reflects their inputs. Through this research, I've learned a lot about myself, in that I'm very patient and willing to listen even in the event that I have a different view on a topic. This made me realise that, listening and taking in the inputs from different level of experts in LSS I learn a lot. I also realised that I was more intrigued by answerers given by the blackbelt participants. They showed a lot of experience and passion regarding LSS.

5.3 Limitations

Some of the participants of this study were pressed for time as they were between engagements during the interview process. Therefore, in some interviews the interviewees were pressed for time which impacted the extent to which they engaged with the interviewer. Some details might have been omitted as a result of the rushed thinking which negatively impacted the interview process.

5.4 (Bagherian, Gerschon, & Kumar, 2025) **Conclusion**

This study looked at how using LSS methods can help improve how efficiently and productively trains are manufactured. By interviewing eleven professionals from the industry, the study showed that LSS has strong potential to improve manufacturing processes. The main problem it addressed was the train industry's ongoing struggle to deliver trains on time while keeping quality high and costs low. These problems were mainly caused by inefficient workflows, too much waste, and inconsistent procedures across different train manufacturing sites.

The findings from both literature and interviews showed that LSS can help solve these issues by cutting waste, reducing variation in processes, and using resources more effectively. Interviewees explained that tools like DMAIC (Define, Measure, Analyse, Improve, Control) and Value Stream Mapping can help find and fix delays and problems in production. The literature highlighted those long-standing issues like delays, poor quality, and going over budget could be reduced with proper use of LSS. These improvements would help train manufacturers deliver on time, improve product quality, and offer better prices in a competitive market.

This as well has also been proven through this study that the implementation and use of LSS principles will help improve those challenges. However various factors should be considered in LSS implementation. The findings from both literature and interviews indicate that using LSS approach which is supported by strong leadership, active employee involvement, and proper planning is important to improving productivity and efficiency in the rail manufacturing sector. Resolving unstable processes, reducing waste, and encouraging ongoing continuous improvement culture can greatly improve performance. In the long run, success depends on bringing together the right people, clear processes, and regular performance tracking to meet customer needs and stay competitive.

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APPENDIX A: Interview questions

(Gomaa, 2025)**"Before we start, I want to assure you that everything you share during this interview will remain confidential. Your identity and responses will be anonymized, and any information you provide will only be used for research purposes. If at any point you're uncomfortable with a question or want to stop, feel free to let me know."**

1. **Background information**

1.1. Position held

1.2. Working experience

1.3. Your organisation sector

1.4. Are you a qualified Lean six sigma belt holder?

2. **Evaluating Factors Affecting Manufacturing Productivity:**

4.6. What are the main factors you believe contribute to or hinder productivity in your manufacturing processes?

4.7. How do external factors, such as supply chain disruptions or regulatory changes, affect productivity in your manufacturing processes?

4.8. How does organisational culture influence productivity in your manufacturing processes?

4.9. What role does leadership play in driving productivity improvements?

4.10. How do employee engagement and morale affect productivity in your organisation?

5. **Using LSS to Enhance Manufacturing Productivity:**

5.4. How would you explain the role of Lean Six Sigma in improving efficiency and productivity of your manufacturing processes?

5.5. What specific Lean Six Sigma tools or techniques do you find most effective for solving productivity issues in manufacturing?

6. **Developing a Roadmap for LSS Implementation:**

6.4. In your opinion, what are the most common challenges encountered during Lean Six Sigma implementation?

6.5. What steps would you recommend for developing a roadmap to implement LSS in a rail manufacturing organisation?

6.6. How do you ensure that LSS improvements are sustained over time?

APPENDIX B: Ethics clearance certificate

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School Ethics Committee
Constituted under the University Human Research Ethics Committee (Non-Medical)

Ethics Clearance Certificate

Ethics protocol number: WBS/BA2768484/425
This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below).

Project title	The application of Lean Six Sigma in the train manufacturing industry to improve productivity
Investigator / Researcher	Mr Lebogang Bambo
Nature of Project	MBA (Research Article)
Decision of the Committee	Approved, provided stakeholders and participants are guaranteed anonymity and confidentiality.
Issue Date of Certificate	24/10/2024
Expiry date	Date of submission of the project / research report
Chairperson	Dr Ayanda Magida ☎ +27 11 717 3953 ✉ ayanda.magida@wits.ac.za

Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

I fully understand the conditions under which I am authorized to carry out the abovementioned research a
I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from th
research procedure as approved I undertake to resubmit the protocol to the Committee.

Signature

25/10/2024
Date: