Executive Summary

This report documents the steps followed in designing a Lean Implementation Roadmap for South African manufacturing companies. A Literature Review on Lean principles and tools is done, after which gaps and challenges of Lean implementation in South Africa are identified through research and two case studies. Two literature sources, namely the House of Lean and an existing Lean Six-Sigma implementation roadmap are used as a basis for designing the new roadmap. The identified Lean challenges unique to the South African manufacturing environment are used to identify specific attributes that are included in the new roadmap.

The final steps of the new Lean implementation roadmap are specified as follows:

- PLAN
    1. Foundation
    2. Employee Motivation
- DO
    3. Training
    4. Pilot Implementation
- CHECK
    5. Assessment
- ACT
    6. Company-wide Implementation

The individual steps are divided into the phases of the Plan-Do-Check-Act cycle and the Industrial Engineering methods used to achieve steps are explained by means of examples. Finally, the new Lean Roadmap is presented graphically to simplify and visualize implementation for managers

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1. Introduction

1.1 Background

The principles of Lean Thinking were first introduced by Toyota in the 1930's, when Kiichiro Toyoda, Taiichi Ohno and others at Toyota came up with a few innovative ideas to improve the process flow of Ford's production model that was most commonly known at the time. Their strategy lead to more continuous flow and a wider variety of products than Ford could offer, and the Toyota Production System (TPS) was invented. The main focus of this system was to shift the focus from individual machines and their performance to overall production and flow through the entire process. By allowing machines to only produce the required amounts of parts, introducing self-monitoring machines and implementing a process-flow sequence of machines, they achieved lower costs, higher quality, shorter throughput times and the ability to adapt quickly to changing customer needs.

Since their success in the 1930's and more significantly after the Second World War, thanks to their philosophy Toyota has evolved into the biggest automotive manufacturer worldwide in terms of overall sales. Even today their success is obvious from their global market shares and vast sales numbers to their lead in hybrid technology and provides the best proof for the accomplishment of Lean Thinking. Toyota's success story has led to a great demand in knowledge about the Lean philosophy, and over the past 20 years an enormous amount of information has been made available through all kinds of channels from books to journal articles and internet publications.

Lean Thinking today has reached many countries around the world and its principles have been adapted to apply to industries beyond manufacturing including logistics, service industries, retail, healthcare, construction and government services.

1.2 Problem Statement

Although Lean Thinking has been very successful for a large number of companies, other organizations in South Africa and around the world are struggling to correctly implement Lean and achieve all of its goals. The following chart based on data gathered by Vermaak (2008) shows the percentage of South African companies that fit into certain industry standards when Lean implementation is concerned.

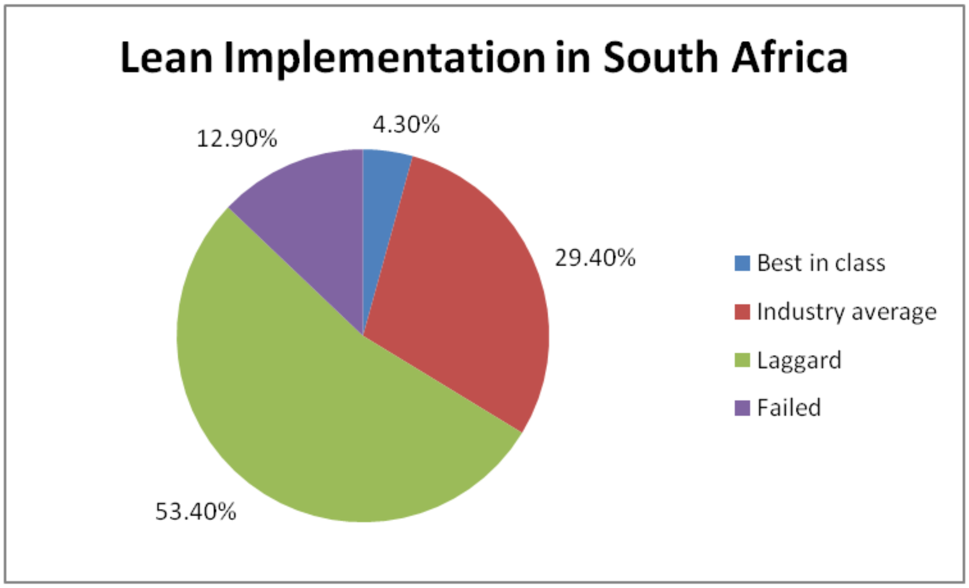

Figure 1: Lean Implementation Standards in South Africa

This chart clearly indicates that more than half of South African companies that have tried to implement Lean have not even reached the standard of industry average. Only 4.3% of companies are considered to be the "best in class".

Middle management and supervisory levels in companies are often overloaded with Muri (unreasonable workloads) and efforts to implement even basic lean practices are often met with serious resistance or complacency. Failure to present key lean initiatives as sustainable management practices, reduces lean to boardroom talk and wish lists. The inherent disciplines of Lean Thinking are also not easy to implement in South Africa and a different approach is often required. The high initial costs of putting Lean Thinking into practice, combined with the extended time it takes for benefits to actually materialise cause further difficulties.

1.3 Project Aim and Scope

The aim of this project is to investigate Lean Thinking and practices in order to develop a Lean roadmap for high impact operational improvements in South African manufacturing companies. The ideal roadmap will ultimately guide managers and other workers to implement the best Lean practices step by step. Appropriate additional material will form part of the roadmap to help managers train staff members of all levels and ensure that the Lean philosophy is applied throughout the company.

Due to the large amount of information and tools within the Lean philosophy, the project is limited to the following:

- The focus is be kept on South African manufacturing companies
- Only certain Lean tools as presented in the Literature review are considered

1.4 Project Approach

The project is completed in the following steps:

1. Conducting a Literature Study on relevant Lean principles, tools and techniques
2. Identifying Literature that is used to support the development of a Lean Roadmap
3. Identifying Gaps and Challenges faced by South African manufacturing companies when trying to implement Lean
4. Designing an Implementation Roadmap to guide companies in Lean implementation by using the right tools to combat identified challenges

2. Literature Review on Lean Tools and Techniques

2.1 Lean Principles and Strategies

The Lean philosophy is based on two focal points: the reduction and elimination of waste and the adding of value for the final customer. Waste (muda) is not only classified as physical scrap, but as every aspect of a process that does not add customer value to the final product. According to the TPS, the “7 Wastes” are classified as follows:

1. **Over-production:** This is considered as the most critical type of waste, since it prevents a smooth flow of products and will most likely reduce quality and productivity. It also typically increases lead and storage times and may cause defects not to be detected earlier. Furthermore, overproduction creates unnatural and unnecessary pressure on work rates and leads to excessive Work in Progress (WIP) stock, which may disturb the physical locations of operations and cause poor communication.
2. **Waiting:** Waiting occurs when time is being used ineffectively. In a typical factory-setting, products or parts that are not currently moving or being worked on are said to be waiting, and therefore wasting time of both the products and the workers. Ideally, there should be a faster flow on a factory shop floor with no waiting time.
3. **Transport:** From an extreme view, any form of transport is seen as waste since transport itself does not add value to any product. The goal is thus to minimise transport of goods and workers as far as possible. Redundant movement and excessive handling also increase the possibility of damage and product deterioration. The distance a product is required to travel from one process to the next is directly proportional to the time it takes to feed back defects and to take corrective action.
4. **Inappropriate Processing:** When simple processes are overcomplicated, for example by using a large inflexible machine for an entire process instead of many smaller, more flexible machines, inappropriate processing occurs. This usually results in poor floor layouts which causes excessive transport and poor communication. Ideally, the smallest possible machine capable of a specific process should be placed right between the previous and subsequent operations.

5. **Unnecessary Inventory:** Unnecessary inventory creates excessive storage costs, as well as taking up space within a factory that could be used efficiently in other ways. It also increases lead times which prevents problems from being discovered quickly and discourages effective communication.
6. **Unnecessary Motion:** This waste refers to ergonomic movements that should be avoided, for example operators having to stretch, bend or stay in uncomfortable and unhealthy positions in order to do their work. Such movements decrease worker morale, productivity and typically lead to reduced quality.
7. **Defects:** Defects are ultimately the most tangible type of waste, and they translate into direct costs. They also indicate the area of opportunity for improvement within the production system.

Value is critical to the Lean philosophy, but is often confused with the reduction of cost. Womack and Jones (1996) classified value as the first principle of Lean which caused Lean to move away from only focusing on reducing typical shop-floor waste and cost to increasing perceived value of customers by adding desired features and reducing wasteful activities. This redefined value as customer requirements instead of simply the opposite of waste. The key is no longer what the shop-floor regards as waste, but what the customer thinks of as wasteful, unwanted or unnecessary.

The relationship between value and cost is graphically shown in figure 1 below by Hines, Holweg &Rich (2004), where products are plotted according to the relative cost-value they offer to the customer. The higher above the equilibrium-line the product is plotted, the more satisfaction can be expected from the customer since this indicates a high ratio between value and cost. If a product is plotted directly on the equilibrium line, it means that for the value added to that product, a customer is willing to pay exactly the same amount as it costs to add that value.

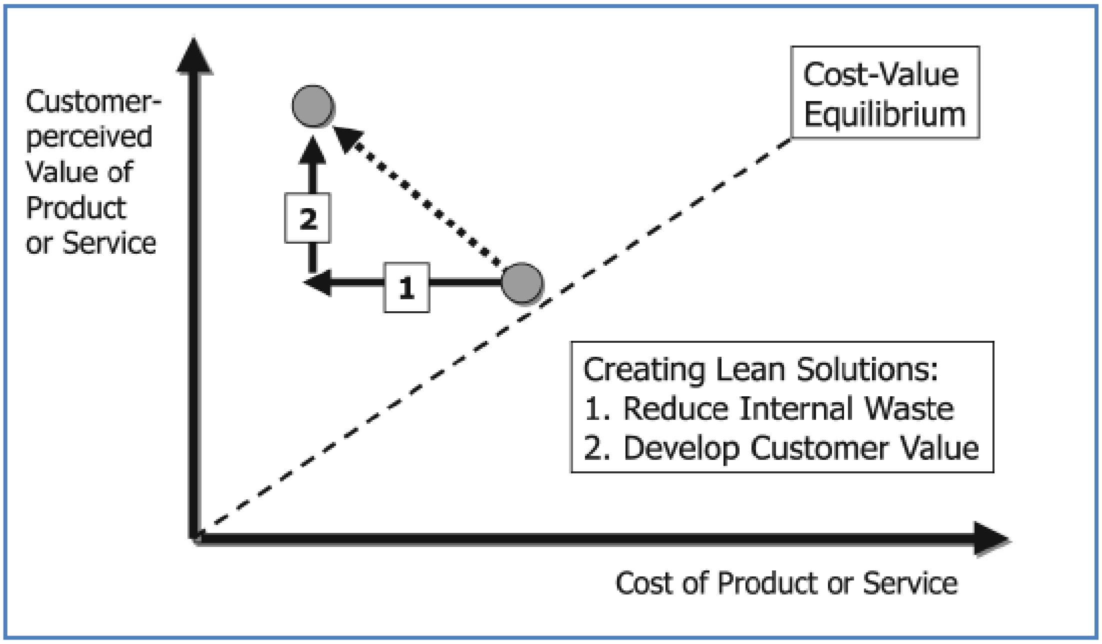

Figure 2: Relationship between value, cost and waste (Hines, Holweg & Rich, 2004)

From Figure 2, it can also be seen that value can be created in two different ways:

1. Value is created by reducing internal waste, and therefore costs associated with wasteful activities.
2. Value can also be created or enhanced by increasing the number of value-adding features to the product without increasing the cost, e.g. introducing shorter delivery times or smaller delivery batches.

2.2 Lean Tools

In order to achieve the lean principles of reducing waste and increasing value, several tools have been developed throughout the past decades of which only a few are discussed below.

2.2.1 The 5S System

The “5S” system is a style of management which is aimed specifically at reducing the seven wastes. The name is derived from the five Japanese acronyms:

- Seiri (organisation)
- Seiton (neatness)

- Seiso (cleaning)
- Seiketsu (standardization)
- Shitsuke (discipline)

As interpreted by Chapman (2005), these Japanese terms can be translated into an English “5S” system as Sort, Set in order, Shine, Standardise and Sustain.

The motto for the 5S system is “There is a place for everything and everything should be in its place”, which exposes problems relating to workflow quickly and efficiently so that corrective action can be taken as soon as possible. The correct implementation of a 5S system will allow for a “visual factory” in order for managers to assess the status of the workplace at a glance. One can immediately see if there is something out of place or if production has slacked or stopped. Process defects can generally be reduced by up to 50%, according to Masaaki Imai in his book, Gemba Kaizen. This point highlights the importance of the 5S system in a Lean environment. The individual steps are explained in more detail as follows:

1. **Sort:**

The first step is for workers to sort out what is not needed in their workspace, so that they can do the required work within the required space. Things that typically accumulate in a workplace include parts, WIP, scrap, documents, packaging materials, tools, machinery and equipment. Although some of these things may be needed for production, much of it is not needed and will generally only clutter a work area and obstruct the flow of work.

2. **Set in Order:**

After having filtered only the necessary materials and equipment for a particular workstation, employers are required to organise their space in a way that minimises their movement and motion as well as the distance that goods have to be transported. The workplace should be organised in such a way that everyone, including supervisors, newcomers and other work teams, can clearly see where everything, including materials, tools and files, belongs. This can be done by using floor demarcations and labels on shelves and files. Any abnormalities in the standard positioning should stand out to anyone.

3. Shine

The "shine" stage of the 5S system refers to cleanliness of the workplace. Workers are required to clean not only their floor space, but also the equipment, tools and machinery. Areas like isles, under tables and storage areas should be included in the cleaning operations. During cleaning, employees must also check whether equipment and tools are in good working order and report it if this is not the case to prevent unpredicted breakdowns.

4. Standardise

To standardise the first three 'S' steps, centralized 5S stations should be set up on the shop floor. These should be equipped with cleaning equipment, tape for colour coding and other materials needed for the specific company's visual management system in order for workers to have quick and easy access to these items when needed. Management should also allocate standard times to the maintenance of the 5S system. A checklist of responsibilities and schedules is usually also posted at these stations.

5. Sustain

The final step of the 5S system is to ensure that the system becomes an integral part of the company's operations. Staff from all levels of the organization are involved in maintaining the system, with each staff member having his or her own responsibility towards it. These responsibilities include implementation, maintenance, performance measurement, feedback and the pursuit of continuous improvement of the system.

2.2.2 Value Stream Mapping (VSM)

Value Stream Mapping is a lean tool focused on increasing the customer value of products from the time an order is placed by a customer until the time the customer receives that product. A Value Stream Map is a special type of flow chart that depicts the flow of materials and information through an organization. Specific icons and symbols known as the "Language of Lean" are used to show every step of the process that a specific product has to go through from the point of order to the point of delivery. The VSM process takes place in three basic steps:

1. Define the product or product family:

The first step is to identify a product or product family for which the value stream will be mapped. Products that undergo similar processes within a factory can be grouped together and share the same Value Stream Map. Magnier (2003) uses the following table as an example to show how different products can be grouped into product families:

			Process				
Description	Product	Product Family	L101 Coils Bending		L101 Unit Brazing	L101 Unit Ass'y	L101 Unit Packing
			Machine	Labor	Labor	Labor	Labor
TWK 530 NBL	22227777-000	1			X	X	X
TWK 530 NBL-OC	22227777-CDT	1			X	X	X
TWK 536 NBL	33338888-000	2	X	X	X	X	X
TWK 536 NBL-OC	33338888-CDT	3		X	X	X	X
TWK 048 NBL	44447777-000	2	X	X	X	X	X
TWK 048 NBL-OC	44447777-CDT	2	X	X	X	X	X

Figure 3: Table showing an example of product family classification (Magnier, 2003)

2. Create the "Current State" Value Stream Map

To get all the information needed for the creation of the current state VSM, it is required to walk through the entire process the chosen product or product family goes through in the workshop. Womack (2006) suggests that this is done by a single person or a small team from beginning to end. Otherwise, if the value stream is divided into smaller parts which are then assigned to various people or small teams, it may create confusion and lead to inaccurate maps that can not be trusted. It is crucial to get the current state map right as "improvement can only be based on accurately identifying the problems with the current state". (Womack J. P., 2006)

The objective of the current state map is to analyse every activity or process step with regards to the value that a specific step adds to the product. A standardized set of icons, symbols and data should be agreed upon to create the current state VSM. A typical set of VSM Process icons can be seen in Appendix A.

According to Hines (1997), each activity in the value stream should be categorized into one of the following:

- Non-Value Adding (NVA)
- Necessary but Non-Value Adding (NNVA)
- Value Adding (VA)

NVA activities represent pure waste and should be banished completely. These may include waiting time, stacking intermediate products and double handling.

NNVA activities do not add customer value to the product, but can not be eliminated completely. Examples of such activities are transporting products from one area to another, unpacking arrival stock, moving tools from one hand to the other etc. These activities can typically only be eliminated by major changes in the operating procedure, e.g. changing the floor layout and requesting delivery of unpacked parts, which will not always be possible immediately.

VA activities transform raw materials or unfinished parts into the final product as the customer wants it. These may include assembly operations, finishing and painting.

To clearly depict the flow of objects and information through the value stream, Womack (2006) suggests that three critical factors are taken note of:

- <u>Flow vs. Stagnation:</u> The amount of inventory throughout the value stream is of great importance. Since the product, in the ideal state, is in constant motion, there is no inventory and customer needs can be integrated in the minimal amount of time.
- <u>Push vs. Pull</u>: This refers to the regulation of production information. Ideally, when flow is continuous, the only required information will come from a customer order, which will initiate the production of the ordered product. In practice however, it is not always physically possible to have continuous flow. In such situations, the ideal state would be for each downstream activity to only signal its upstream activity of its immediate requirements. These requirements should then be met quickly and in the correct

amounts. The TPS has put its major focus on such a pull-system, commonly referred to as Just-In-Time (JIT). For the purpose of indicating inventories on a VSM, a triangle is placed where there is inventory and a number with the amount of inventory is put inside. The flow of information is plotted by using arrows that show the starting point, direction and end of production instructions.

Finally, the most significant factor of the current VSM is the overall throughput time. This time is measured from the time production of a product is started, until it is delivered to the customer. Reducing throughput time was the greatest goal for Taiichi Ohno when designing the TPS. This time is the most accurate indicator of how the whole value stream is performing. The time taken for VA activities as opposed to the time taken for NVA activities is also noted, since the latter will specifically be targeted and attempted to be reduced. An example by Magnier (2003) illustrates this aspect in a simple way:

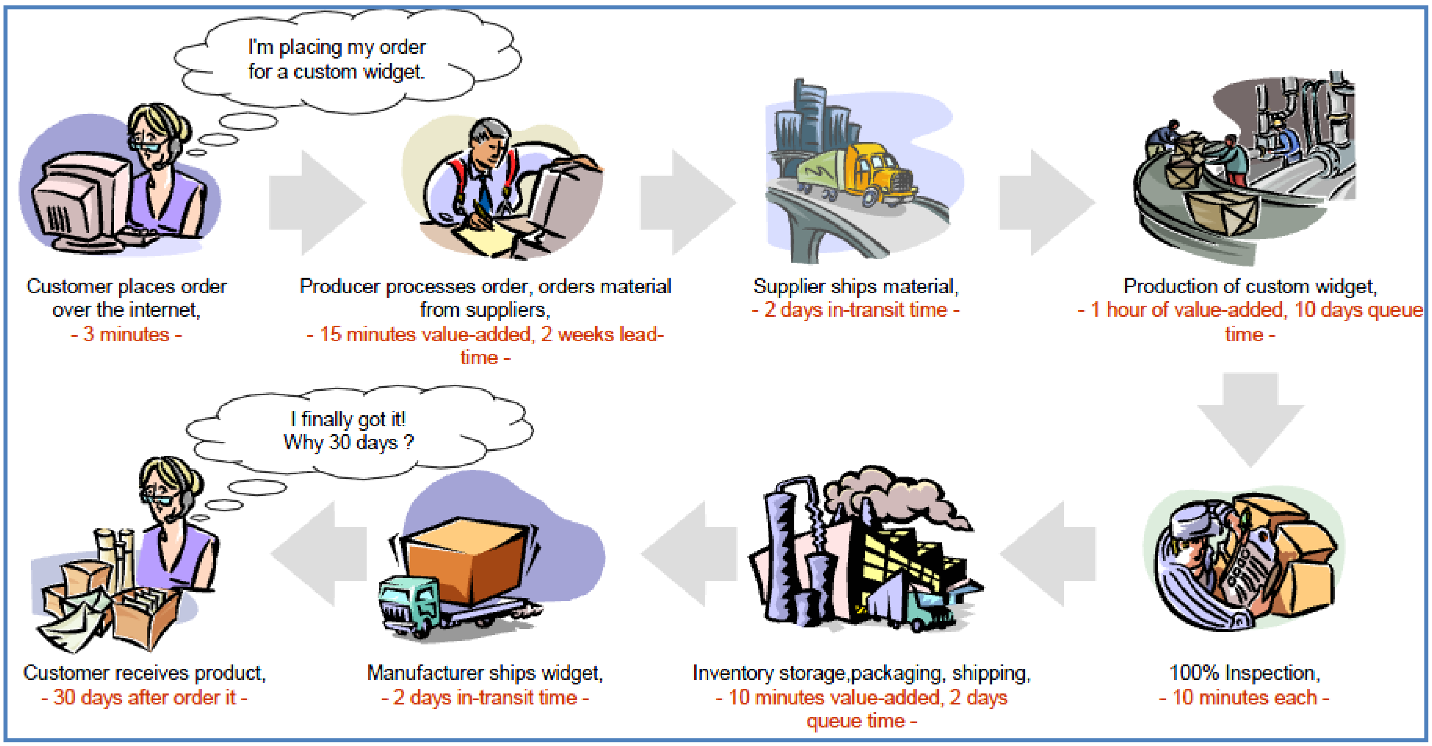

Figure 4: Illustrated example of VA time vs. NVA time in a value stream (Magnier, 2003)

In this example, the total throughput time is 30 days, whereas the total VA time is only 1 hour and 45 minutes. The objective of VSM is to reduce the overall throughput time by focusing on reducing the NVA time.

When the current state map is completed, there should be a clear picture of where problems arise or where NVA activities can be reduced or eliminated. A List of possible improvements is made which will be used in creating the future state VSM in the next step.

An example of a completed current state VSM of a generic manufacturing company is also included in Appendix B of this report.

3. **Create the "Future State" Value Stream Map**

Once the current state VSM is completed, the focus is placed on possible improvements in the value stream to create a more optimal VSM of what a "Future state" should look like. As mentioned before, two key principles in finding opportunities for improvement are reducing or eliminating NVA activities where possible and attempting to create continuous flow of products as far as possible. Activities such as reworking or storage are NVA and should be eliminated completely, while individual processes should be organized to create continuous flow. According to Womack (2006), these are the two methods of value stream improvement with the highest payoffs, as they "eliminate waste while making the customer happier because of better quality and rapid delivery" (Womack J. P., 2006).

Another step in improving the current state value stream is leveling the output of the stream. One value stream may have to be divided into several smaller value streams to accommodate products with different processing needs and challenges more appropriately. The point of the value stream at which a customer order is transformed into a production instruction is known as the pacemaker step. This point has to be identified, after which a standard inventory is assigned to it which permits upstream and downstream processes operate smoothly. First-In-First-Out scheduling is then used downstream of the pacemaker and pull signals are used upstream. The pacemaker point is typically where the ultimate specifications of a product are set. Where products are made-to-stock, it will be at the assembly point, at the downstream end of the value stream. For made-to-order products, it will commonly be at a point further upstream. The aim of a large enough standard inventory is to buffer fluctuations in demand, while not compromising on quick response time to customer orders. In this manner, most mura and muri can be removed, leading to better quality and lower costs.

Taking into consideration the above mentioned principles, a new map is laid out, and the value stream operations are adjusted accordingly. The implementation of future state maps is expected to result in throughput time reduction, cost reduction and quality improvement. An example of a future state VSM is displayed in Appendix C.

2.2.3 A3 Management

The Name "A3 Management" is derived from the international standard size of paper, A3 (approximately 11 by 17 inches). The main principle of this management style is that every problem within an organization can and should be visualised on a single A3 sheet of paper. "This enables everyone touching the issue to see through the same lens" (Shook, Managing to Learn: Using the A3 Management Process to Solve Problems, Gain Agreement, Mentor and Lead, 2008). A3's of different companies will usually rest on the same basic strategy, but will vary in specific layouts and wording according to unique environments and requirements. Since its initial implementation by Toyota, the A3 has proven to be a powerful tool for decision making, planning, problem solving and proposals.

According to Shook (2009), the following elements are displayed on a single sheet of paper to form a typical A3:

- **Owner/Date** identifying the person who "owns" the problem and capturing the date it was last revised on
- **Background** which portrays the situation that needs attention in the appropriate context
- **Current Conditions** explaining what is already known about the problem
- **Goals/Targets** which specify the wanted outcomes

- **Analysis** of the factors that form the gap between the current conditions and the desired outcomes
- **Proposed Countermeasures** which are believed to counter the problem or reach the desired outcomes
- **Plan** indicating who will be responsible for what and when in order to achieve the set goal(s)
- **Follow-up** to plan when the situation will be revised

As mentioned before, the layout of different A3's may vary, but it is important to create each A3 in such a way that is clear, easy to understand and logical. The elements should be displayed in a logical chronological order that will not confuse any reader. Shook (2009) states that the best way to create A3's is to let employers design their own unique A3 based on the above guidelines and not merely give them a generic template to fill in. This method is said to enhance creative thinking and problem solving. Different tools that can be used to create the different sections of an A3 are listed in the table below, as used by Shook (2009):

Section of A3	Storytelling Tools
Background	Graph, Sketch, Photographs
Current Conditions	Tally Sheet, Pareto Diagram, Sketch, Current-State Map, Histogram, Scatter Diagram, Control Chart, Graph, Photographs
Goals/Targets	Graph, Sketch, Photographs
Analysis	Control Chart, Cause-and-Effect Fishbone, Relation Diagram, Histogram, Tree Diagram, Pareto Diagram, Sketch, Graph, Scatter Diagram, Photographs
Proposed Countermeasures	Diagram, Chart, Sketch, Future-State Map, Graph, Evaluation Matrix, Photographs
Plan	Gantt Chart
Follow-up	Sketch, Chart, Photographs

Figure 5: Table of possible A3 Tools (Shook, 2008)

An example of anA3 template is included in Appendix D of this report.

A3 Management is also based on the Plan-Do-Act-Check (PDCA) cycle, and the various tools can be categorized into this cycle as illustrated by the following table from Sarkar (2010):

A3 Steps	PDCA Cycle
Background	Plan
Problem Statement	
Goal Statement	
Root Cause Analysis	
Countermeasures	Do
Effect Confirmation	Check
Follow Up Actions	Act

Figure 6: Table comparing A3 steps with the PDCA cycle (Sarkar, 2010)

A3 reports not only play a practical role when implemented by a company, but also foster a certain way of mentoring and learning which has proven to be very successful at Toyota (Shook, 2009). It encourages root cause analysis, effective communication through all levels of an organization and mutual learning.

2.2.4 Six Sigma

Although the question whether Six-Sigma is a Lean Tool or an alternative approach to Lean is still debated by many, for the purpose of this report it will be considered as a Lean tool.

"Six Sigma Management is the relentless and rigorous pursuit of the reduction of variation in all critical processes to achieve continuous and breakthrough improvements that impact the bottom line of the organization and increase customer satisfaction." (Gitlow, Oppenheim, Oppenheim, & Levin, 2005) Six Sigma was first implemented by Motorola in the mid 1980's when employees started counting defects by a common method which brought them to the conclusion that significant improvements in quality can be made when focus is placed on customer requirements. The results of quality and performance within the organization proved this method to be highly successful and by the late 1980's Mikel Harry, a Motorola architect had founded the Six Sigma Academy to introduce his methods to other major companies like IBM, GE and Kodak. Six Sigma has been proven to be highly successful in increasing performance and quality for major organizations ever since.

The main goal of Six Sigma implementation in the manufacturing environment is to design processes in such a way that only 3.4 defects per million opportunity (DPMO) are produced. When analysing the output of a specific process, the normal distribution should take up a maximum of half the tolerance allowed by the specification limits for that process. The name Six Sigma is derived from the principle that the distance from a process's distribution mean to both its upper specification limit (USL) and lower specification limit (LSL) is no more than 6 times the distribution's standard deviation (σ). When this is achieved, the process will produce the desired rate of 3.4 DPMO. Figure 7 illustrates the Six Sigma principle:

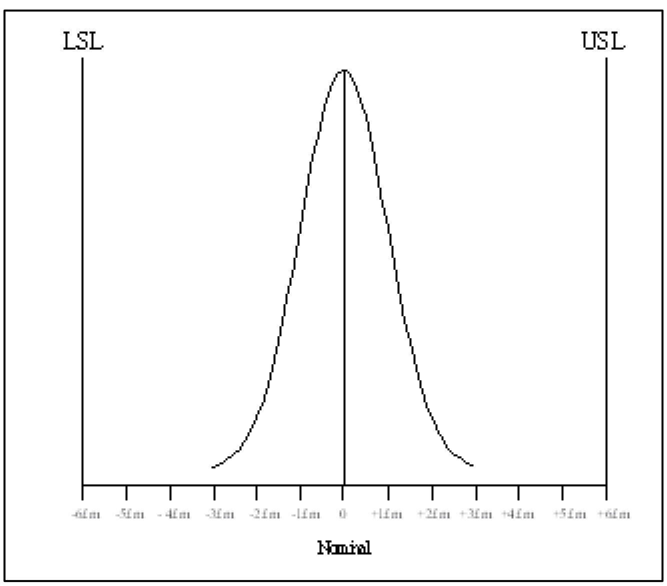

Figure 7: The Six Sigma Process with no shift in Mean (Gitlow, 2005)

In order to achieve a Six Sigma process, the DMAIC model is used. The individual letters of this acronym stand for the 5 phases that the process should undergo, namely Define, Measure, Analyse and Improve. This concept is graphically presented in Figure 8 below, and the main goals of each phase are briefly described.

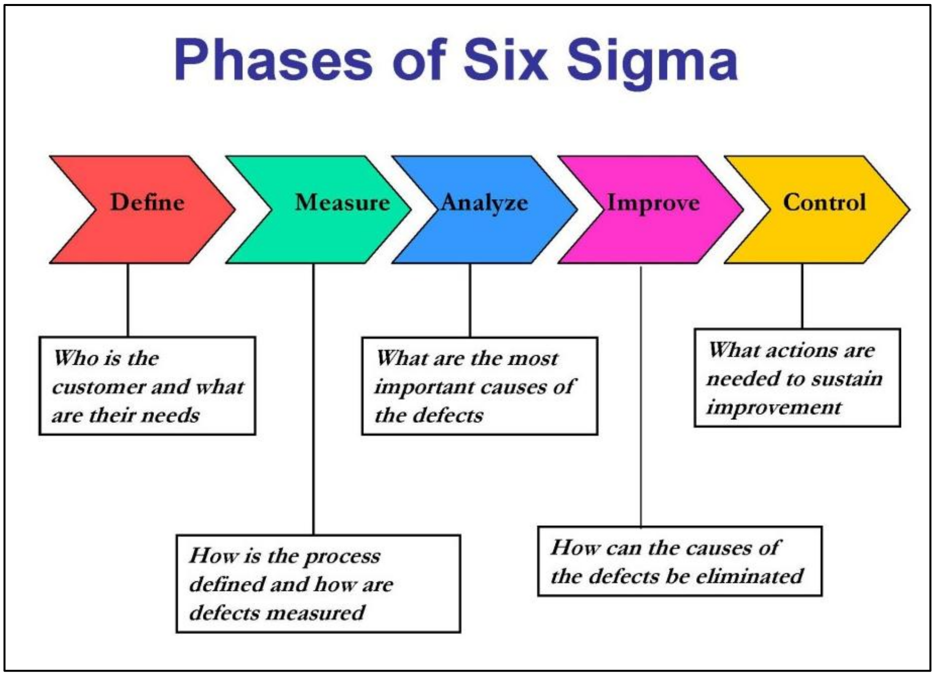

Figure 8: The DMAIC phases of Six-Sigma (Shapiro & Weeks, 2005)

The employees of an organization who are involved in implementing Six-Sigma have very specific roles and responsibilities, for which training can be received and official certifications awarded. The following table by Pershing, Stolovitch & Keeps (2006) summarises the various roles and responsibilities of Six-Sigma role players.

Role	Responsibilities
Senior Executives	• Create vision • Define strategic goals and measures • Establish business targets • Create positive environment and enforce accountability
Senior Deployment Champion	• Manages Six Sigma throughout organization • Designs Six Sigma infrastructure and support systems • Uses performance goals for business units • Reports progress and acts as liaison to senior executives • Establishes communication plan with deployment champions
Deployment Champions	• Responsible for deployment within division or business unit

	• Work with leaders to determine goals and objectives and ensure alignment • Identify opportunities that are aligned with business goals • Facilitate prioritization of projects • Establish and execute training plans • Develop unit or division communication plans • Report deployment status to senior deployment champion • Select project champions and remove barriers for teams
Project Champions	• Select and mentor black belts • Lead project identification, prioritization, and project scope • Remove black belt barriers and align resources • Work with deployment champions and process owners
Master Black Belt	• Expert on Six Sigma tools and concepts • Trains black belts and ensures proper application of methodology and tools • Coaches and mentors black belts and green belts • Maintains training material and updates as appropriate • Assists champions and process owners with project selection, project management, and Six Sigma administration
Black Belt	• Responsible for leading, executing, and completing projects • Teaches team members the Six Sigma methodology and tools • Assists in identifying and refining project opportunities • Reports progress to project champions and process owners • Transfers lessons learned to other black belts and

	organization • Mentors green belts
Process Owner	• Is team member • Takes ownership when project is complete • Responsible for maintaining project goals • Removes barriers for black belts
Green Belt	• Trained in a subset of Six Sigma methodology and tools • Works small scope projects, typically in own work area • Effective member of black belt's team

Figure 9: Table of Six-Sigma Roles and Responsibilities (Pershing, Stolovitch & Keeps, 2006)

2.2.5 Just In Time

The Just In Time (JIT) philosophy was introduced by Kiichiro Toyoda in the 1930s. It is based on the idea that only exactly what is needed is produced only exactly when it is needed. This means that each step of a value stream "pulls" the only the required amount of material or products from the previous step when it is needed, eliminating stock overloads and unnecessary buffers. "The idea is to replace complex scheduling systems-depending on centralized accumulation of information and complicated formulae-with simple, intuitive systems that work much better while dramatically reducing the amount of inventories along a value stream." (Vermaak, 2008)

According to the TPS, two simple rules must be followed for the implementation of JIT:

1. Standard Inventory has to be calculated for every step in the value stream to prevent the downstream step from having to wait. This inventory consists of buffer stock, which is ready-made goods that can be dispatched if problems arise with the delivery for downstream customers, safety stock, which is raw material that can be used when upstream suppliers can not deliver, and shipment stock, which is finished goods that are ready for shipment.
2. The pacemaker step has to be selected. As the name suggests, this is the step in the value stream that determines the pace of production, as it is usually the most prominent bottleneck. Additional buffer stock has to be in place for this step, so that normal

fluctuations in demand can easily be dealt with. This will ensure the smooth operation of value stream steps upwards from the pacemaker step by leveling demand for extended periods.

2.2.6 Leveling

The goal of Leveling *(Heijunka)* is to stabilize production on the shop floor and is said by Vermaak (2008) to be crucial in the successful implementation of Lean. Heijunka includes both leveling production by volume as well as by product or product mix. The main idea of Leveling is to determine long-term demand so that production processes can run smoothly accordingly.

Due to the fact that customer demand is usually variable, a company has to establish a standard inventory of finished goods for make-to-stock goods. For make-to-order items, a stock of parts just before the point of customization has to be calculated. This inventory size will be dependent on the degree of demand variability, the production process stability and the frequency of shipments.

The successful implementation of Leveling will thus create a smooth flow through an organization, cutting costs through reduced inventories along all stages of the value stream.

3. Basis for a Lean Roadmap

The successful implementation of Lean by various companies around the world and its rising popularity over the past three decades have caused a broad interest in the topic and a wide variety of literature has been published by experts, including implementation roadmaps and training material. The aim of this project is to develop a Lean implementation roadmap specifically for South African manufacturing companies, but it will be based on an existing model which will be introduced in this section.

3.1 Original Lean Six-Sigma Roadmap

The Lean Six-Sigma Roadmap on which this project will be based was developed by Mehta (2005). The roadmap consists of ten phases, which are:

1. Management commitment
2. Establishment of communication channels
3. Basic training: Lean, Six-Sigma and product attributes
4. Creation of an organizational framework
5. Development of an implementation plan
6. In-depth Training: Lean and Six-Sigma
7. Pilot implementation: 5-S and VSM
8. Pilot Kaizen Implementation
9. VSM of company-wide processes
10. Company-wide deployment of Lean and Six-Sigma

To successfully implement Lean using this roadmap, Mehta (2005) states that it is of utmost importance to complete one phase before going on to the next. Although this might take more time than expected by managers, the chances of failure will be less than when trying to complete the ten phases as fast as possible. The steps of the roadmap according to the ten phases are graphically presented below:

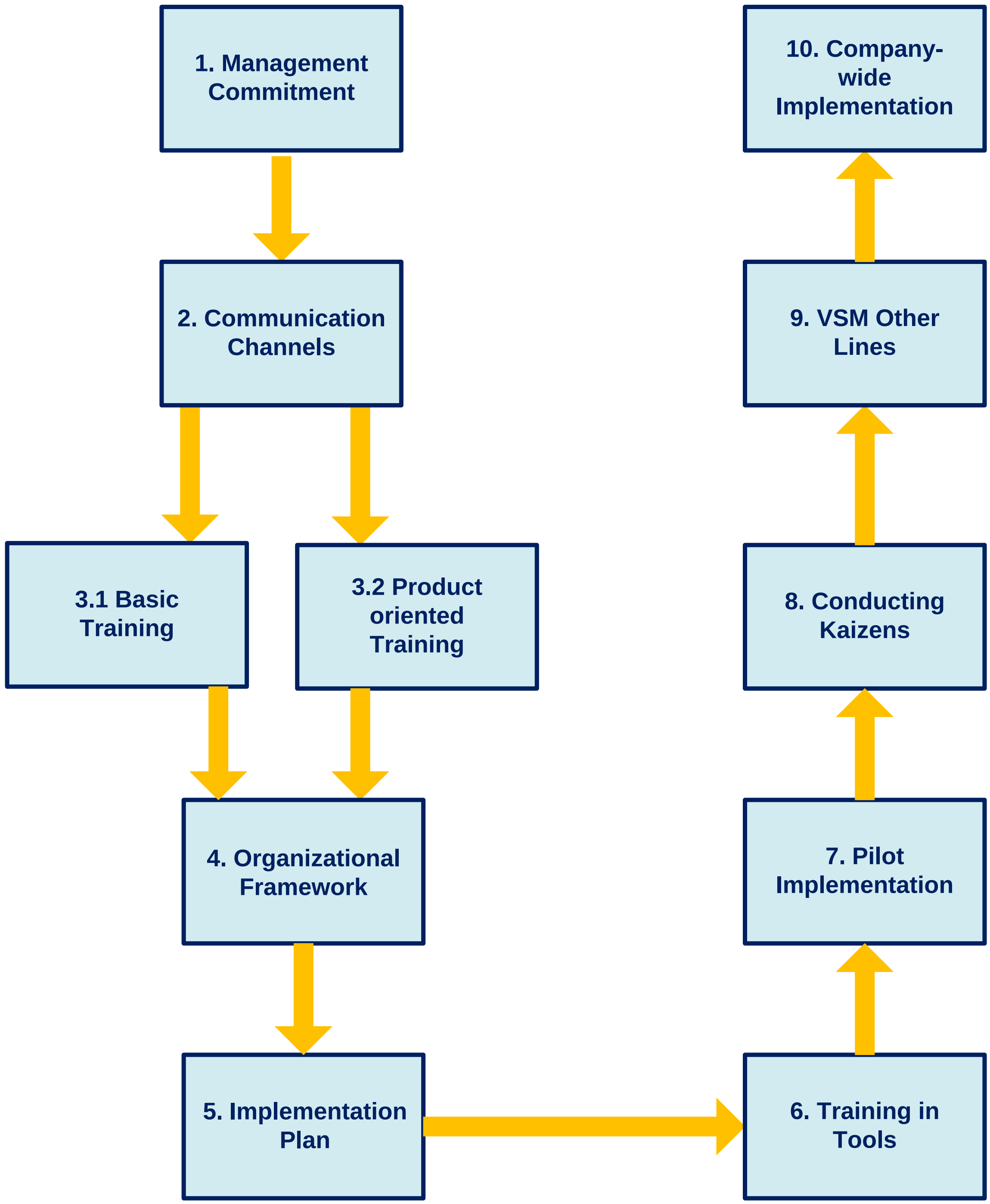

Figure 10: Graphical Interpretation of the Original Lean Six-Sigma Roadmap

Phase 1: Management Commitment

Mehta (2005) describes this phase as the most important of the entire roadmap. Managers need to show their complete commitment to Lean by composing an open signed letter which clearly describes the company's ideas of what Lean and Six-Sigma are and how they plan on staying on track with the implementation. This letter should be displayed throughout the company and read before meetings to keep the focus. Mehta also states that "without a firm commitment companies are better off not embarking on the Lean Six-Sigma journey" and that employees will not take managers seriously if the managers themselves are not entirely convincing and committed to the strategy. Before starting the Lean Six-Sigma transformation, managers themselves need to be thoroughly familiar with the Lean principles and tools that need to be implemented, and once they have committed to implement Lean Six-Sigma, they should not lose focus or get discouraged by unmotivated employees. It is also the manager's responsibility to strengthen the relationship between management and employees, to ensure an environment in which teamwork, as required by Lean Six-Sigma, is possible. This involves apologizing for past mistakes and correcting these wherever possible. The time it takes to complete phase one is estimated at 1 to 2 months by Mehta.

Phase 2: Establishment of Communication Channels

Once Phase 1 has been completed, it is necessary to clearly convey the company's goals and future plans to every employee. The daily performance of the company should also be conveyed to the employees since this will ignite a sense of direction and achievement. A practical example of an effective communication channel, as described by Mehta (2005) is a light pole with green, orange and red lights to indicate the company's current performance. A chart with monthly and annual achievements can be placed next to this pole to display the company's past performance and compare it to the current level of performance. Employees will most likely be eager to better performance or at least stay on track. Wherever possible, Mehta suggests that daily production meetings take place to ensure effective and constant communication between management and employees. This phase should take around 3 to 4 months to complete.

Phase 3: Basic Training: Lean, Six-Sigma and Product Attributes

For the basic training in Lean and Six-Sigma, Mehta (2005) suggests using the "Hewlett Packard Method" which is a top-down approach of training employees. The manager first trains his subordinates, who then teach theirs and so forth until the last shop floor worker has received basic training. The focus should be kept on hands-on experience and involvement of all levels of the organization, to ensure a thorough understanding of Lean Six-Sigma principles and tools. The importance of the product design and attributes should also be considered and conveyed in this phase. According to Mehta, only 23% of the product cost locks up 70% of the manufacturing cost of a product. Hence it is important to implement the principles of designing the product for ease of manufacture (DFM) and ease of assembly (DFA). To further simplify the processes of manufacture and assembly, processes and parts should be standardized as far as possible. This phase will take up to 6 months to complete.

Phase 4: Creation of an Organizational Framework

For the successful implementation of Lean Six-Sigma, any organization needs to clearly identify the key players and their roles and responsibilities with regards to Lean Six Sigma implementation. The Lean Six Sigma champions should be selected from top management and these individuals will together form the steering committee, which will be in charge of sponsoring the Lean Six Sigma projects and clearly identifying the objective of each project. The Lean Six Sigma black belts must also be identified in this phase and they will serve as Lean Six Sigma project coordinators. The role descriptions for both the champions and the black belts must be clearly identified, as well as the metrics that will be used to monitor the performance and progress of the Lean Six-Sigma initiatives. The roles of the shop floor employees must also be considered in this phase. Since they play a key role in the success of Lean Six-Sigma, they have to understand what is expected of them but also how the implementation will benefit them. Mehta (2005) refers to this concept as "What's in it for me" (WIIFM) and suggests that proper incentive plans and gain sharing ideas are developed in this phase. Phase 4 is said to take 7 to 8 months to complete.

Phase 5: Development of Implementation Plan

In this phase, the actual practical implementation plan of Lean Six-Sigma is developed. Since the requirements and operations of every company differ, this is the phase where no generic template can be considered and the champions have to design the implementation plan unique to their organization, identifying the right tools for their specific conditions and needs. The implementation plan should include specific events, methods to monitor the progress and specific goals and deliverables that need to be met. This phase takes 8 to 10 months to complete.

Phase 6: In-Depth Training: Lean and Six-Sigma

Once the implementation plan is clear to every employee, it is time for in-depth training of all employees. A hands-on approach is required in this phase and workers must be trained in the concepts of 5S, VSM and Kaizens, all of which are explained in the literature review. To thoroughly train everyone and complete this phase is estimated to take around 11 to 13 months.

Phase 7: Pilot Implementation: 5-S and VSM

A single line of an organization is chosen in this phase to run a pilot implementation of 5S and VSM on. In this phase, it is important to encourage team building and have employees conduct root cause analyses for problems of the specific line. This phase may take 12 to 14 months for completion.

Phase 8: Pilot Kaizen Implementation

After 5S and VSM have successfully been implemented on the pilot line, it is also important to conduct Kaizens for the same line, in which only one specific problem of the line is focused on. These Kaizens should take place in the form of 3-5 day long events, depending on the severity and magnitude of the identified problem. Teams should be formed and possible solutions brainstormed. This phase will take 17 to 18 months to complete.

Phase 9: Value Stream Analysis of company-wide processes

The pilot line that was used in Phases 7 and 8 will now serve as a model for the company-wide deployment of 5S, VSM and Kaizens. This can be achieved by assigning individual lines to teams who will be responsible for them specifically. It is however also very important to understand the integration and interaction of the different value streams to get a holistic view of the organisation. Other tasks that have to be completed in this phase are the erection of bulletin boards for visual communication within the organization and the identification of procedures to form, organize and disband teams. It is required that the Lean champions and coordinators help and encourage the new teams in this phase. The estimated time frame for phase 9 to be completed is 19 to 24 months.

Phase 10: Company-wide deployment of Lean and Six-Sigma

In Phase 10, teams responsible for 5S, VSM and Kaizens are deployed in the rest of the company. Metrics for monitoring the company's performance and progress as well as bulletin boards to display these are established. It is important for Lean Champions and mentors to be actively involved in helping and guiding the individual teams in this phase, which takes around 25-36 months to complete.

The Lean Six-Sigma Assessment

To ensure the company's correct implementation of the individual phases, certain metrics have been established which are ranked on a scale of 1 to 7. For a company to proceed from one phase to the next, a minimum score of 6 out of 7 has to be achieved for every metric in that specific phase. The official assessment sheet including the various performance metrics can be seen in Appendix E.

3.2 The House of Lean

The principles of Lean as introduced by Toyota are commonly summarized graphically by "The House of Lean", which is shown in Figure 11 below.

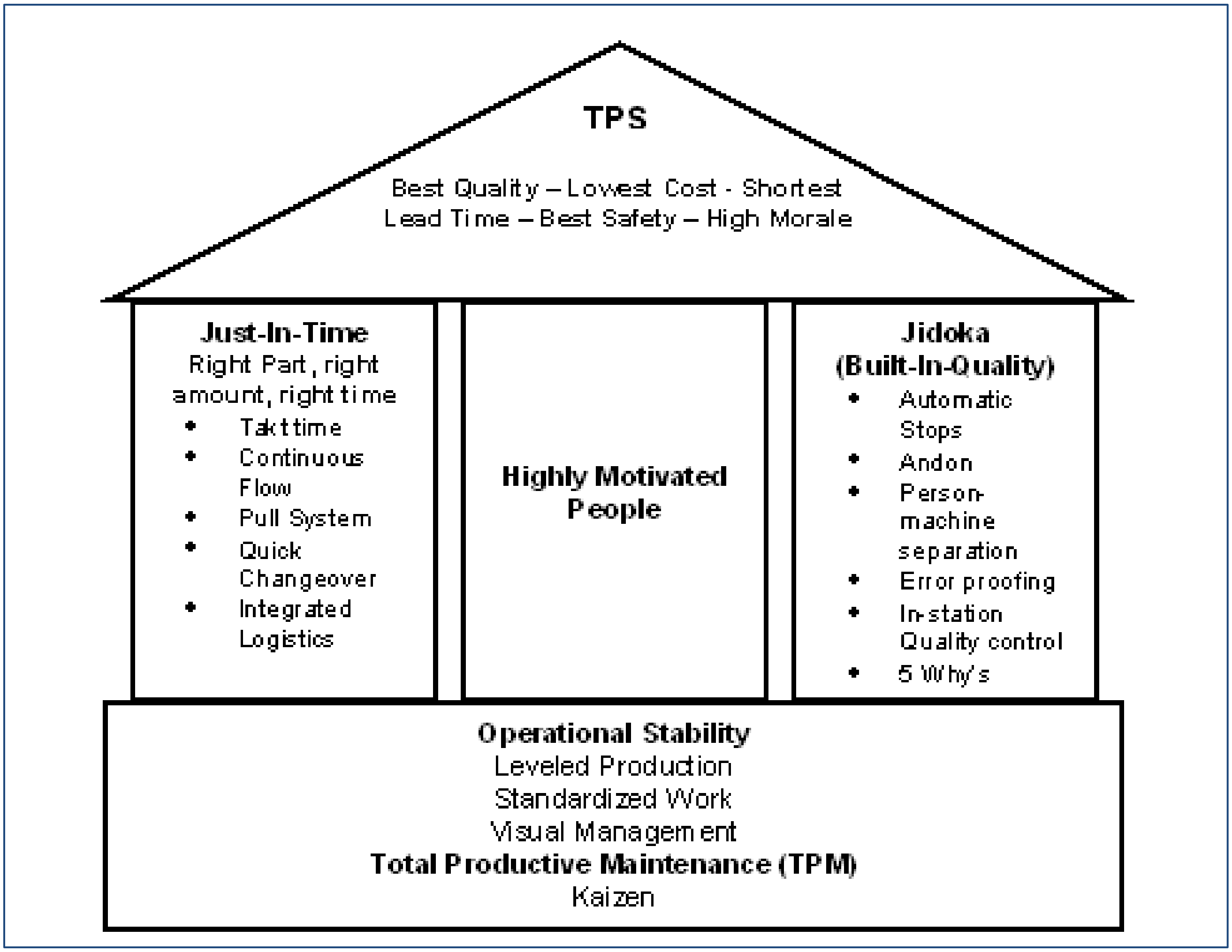

Figure 11: The House of Lean (Schlichting, 2009)

The House is made up of a base, three pillars and a roof that represent the interdependence of the elements in order to achieve a successful Lean implementation.

The base indicates that the most important prerequisite for implementing Lean is operational stability. As can be seen from the figure, this is achieved through leveled production, standardized work and visual management. Total Productive Maintenance (TPM) also forms part of the base, as it is extremely important to have a preventative maintenance plan in place if considering implementing Lean. If a company has not achieved operational stability and TPM, the foundation for Lean is not in place and an attempt to implement Lean will most probably fail.

The three pillars of the house illustrate the main tools that are used to implement Lean once the base has been “built”. The first pillar is called “Just in Time” and represents the aspect of customer orientation. It focuses on the idea that only what is needed should be produced, when it is needed and how much of it is needed, all from the view of the customer. The pillar includes the tools that can be used to achieve the “Just in Time” production plan.

The second pillar shows the importance of a company’s employees in the implementation of Lean. Without “highly motivated people” across all levels of an organization, trying to implement Lean will surely fail. This pillar is strategically placed in the middle of the house, indicating that employees are the core of Lean implementation.

The third pillar is called “Jidoka”, a term that was initially introduced by Toyota founder Toyoda Sakichi and means “built in quality”. The tools that are available to achieve this form of quality are shown within the pillar and include implementation of the Andon line, which lets employees call for help immediately if they face a problem with the production line and will even permit the line to stop if that problem can not be fixed in a given amount of time.

Finally, the roof of the House of Lean stands for the achievements that can be expected if the base and the three pillars are in place. The ultimate achievement is the successful implementation of Lean, which will bring with it best cost, lowest quality, shortest lead time, best safety and high morale as viewed by industry best practices. In the ideal case, where Lean has fully been implemented as discussed above and illustrated by the House of Lean, the following goals are said to be achievable:

- 80% reduction in lead time
- 50% reduction in inventory
- 40% reduction in warehouse and manufacturing space requirements
- 70% reduction in set-up times
- 80% improvement of operational reliability
- 50% improvement in quality

4. Gaps and Challenges of Lean Implementation

The principles and strategies to implement Lean as discussed in the previous chapter seem quite simple and surely promise attractive achievements when implemented correctly. However, the amount of companies that have successfully implemented Lean to such a level that it can be compared to Toyota and other leading companies is significantly small. Although the methodology and principles of Lean seem quite simple and logical, the practical implementation or attempt thereof has yielded great challenges for organizations both internationally and in South Africa.

It is expected that international and South African companies face the same challenges, but given the unique background and current situation of South Africa, challenges that are specific to this country have to be identified. The general challenges of Lean implementation will be discussed first, followed by a review of the challenges faced specifically by South African organizations.

4.1 International Challenges

The exact reasons why companies fail to successfully implement Lean have proven to be extremely difficult to pinpoint, since very few are willing to discuss their challenges openly. The problems that are faced when implementing Lean are also perceived differently by employees according to which aspect of Lean implementation they are faced with. In his Master thesis "Sustaining Lean Improvements" Christopher Schlichting (2009) summarises the challenges faced by companies as explained by experts in online sources. 32 online sources were consulted and the data that was found through this search could be divided into seven general categories, namely:

- Missing management support
- Lack of employee involvement
- Lack of customer focus
- Operational stability
- Financial constraints
- Use of incorrect tools

- Rapid lean conversion

Rapid lean conversion refers to the notion of some managers that once Lean has been implemented the benefits can be visible in 6 to 24 months. However, Lean is not a "quick-fix" and this idea goes against the principle of continuous improvement, which states that improvement is never completed and better outputs should always be strived for. The rest of the terms are self explanatory and will not be discussed in detail. A pie chart of the reasons for Lean failures as presented by Shlichting (2009) is shown in Figure 12 below.

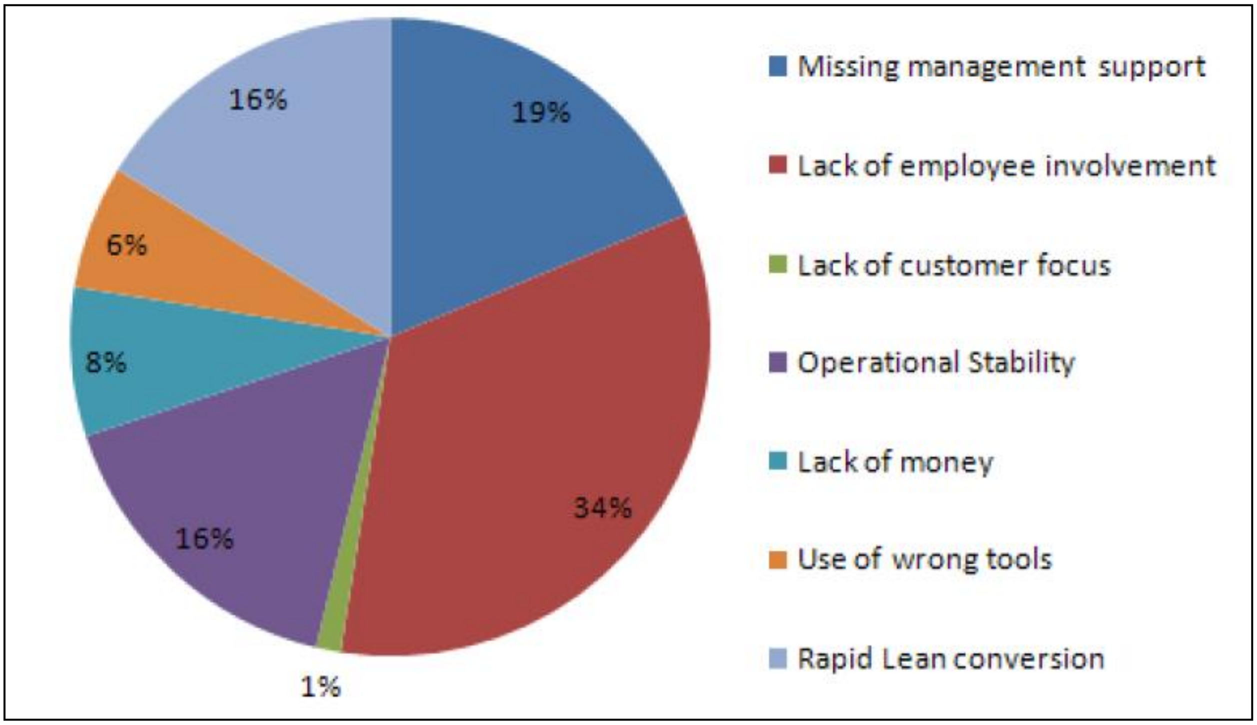

Figure 12: Reasons for Lean Failures worldwide (Schlichting, 2009)

As can be seen from the chart above, the four main reasons for general failure of Lean implementations are:

1. Lack of Employee Involvement
2. Missing Management Support
3. Operational Stability
4. Rapid Lean Conversion

4.2 Factors influencing Lean implementation in South Africa

The success of the TPS is often associated with the highly efficient and disciplined Japanese work culture. Although the Japanese culture definitely plays an important role in Toyota's past and growing success, it is also part of their global philosophy to adjust principles and adapt business strategies and operations to the country in which an organization is situated. The motto "Think globally, act locally" conveys this idea pretty well. It is therefore important to acknowledge certain country-specific elements that could impact the implementation of Lean in South African organizations. In his doctoral thesis "Critical Success Factors for the Implementation of Lean Thinking in South African Organisations" Vermaak (2008) lists some aspects specific to South Africa that should be considered when attempting to implement Lean. These include:

- Culture
- Skills shortage
- Unemployment
- Resistance by Trade Unions
- Distance

These individual topics will be discussed and explained in the following sections.

4.2.1 Culture

The unique South African culture entails a number of factors that could be problematic when trying to implement Lean in an organization. Vermaak (2008) states that ethnic differences are a big cultural factor that impact on the implementation of Lean. Lean is focused on working in teams, which seems to be problematic when trying to involve members of different ethnicities. While the spirit of "Ubuntu" is prominent in the black culture and these people prefer to work in teams, whites are often more comfortable working on their own and getting their work done without interference from other employees. The team-oriented spirit of Ubuntu, which is a Zulu word describing the notion that "I am who I am because you are who you are", can be compared to the Japanese group-oriented culture. The spirit of Ubuntu should therefore be encouraged in the attempt of incorporating cultural views with the implementation of Lean.

4.2.2 Skills Shortage

In his thesis, Vermaak (2006) also expresses concerns about the skills shortage across all sectors in South Africa. Although there seems to be enough basic knowledge to keep organizations running, there is a lack of expertise skills that are often required, also in the case of Lean implementation. The issue of Employment Equity poses another challenge to South African managers. Where on the one hand they are forced by legislation to employ people from previously disadvantaged backgrounds, they also have to try to employ the person that is best suited for the job. These two requirements often conflict with each other and make decisions for managers extremely difficult.

4.2.3 Unemployment

According to Stats SA (2012) the official South African unemployment rate is 24.9%. Some experts believe that when including people that have given up looking for jobs the figure would be closer to 40%. Since the philosophy of Lean is to employ the least number of people necessary to do a job, the high unemployment rate is a big obstacle for managers trying to truly implement lean. To lay off a significant number of employees is not only made difficult by labour laws in South Africa, but should also be questioned morally and ethically when considering engineering ethics and professionalism.

4.2.4 Resistance by Trade Unions

South Africa's political past has brought about an adversarial relationship between managers and employees, and although the new political situation does not encourage these adversities anymore, there still seems to be a constant conflict between employers and employees. In a typical South African scenario, every change that is proposed or introduced by a manager must be approved by the employees and their trade unions. This makes it difficult to implement Lean if the employees are not satisfied with the changes that will affect them and their daily duties. It is therefore particularly important to convince employees of all levels of the benefits of Lean for the company as well as for themselves to keep them and the trade unions satisfied.

4.2.5 Distance

Vermaak (2008) mentions that compared to Japan, where the distances between manufacturers and suppliers are relatively small and manufacturers can practically order the needed parts when they are needed, South Africa faces another challenge. South African manufacturers often use parts or materials that have to be imported from various countries and commonly have to spend a few weeks on a ship to reach their destination. Just in Time is extremely difficult to implement in such a scenario which is quite typical for South Africa.

4.3 Case Studies to Investigate Lean Challenges

To confirm the relevance of the gaps and challenges faced by South African manufacturing companies when trying to implement Lean and Six-Sigma, two different manufacturing companies in South Africa were consulted about their specific challenges with Lean implementation. As mentioned earlier, most companies are not comfortable with publishing their problems or concerns, and the two companies under study are no exception. For the purpose of this report, the companies will therefore remain anonymous, but a short profile on each is given to explain how they are affected by Lean implementation and its challenges.

4.3.1 Company A: Chemical Plant in Johannesburg

Company A is a division of a German chemical company which operates in many countries around the world. It is divided into four major areas, namely North America, South America, Europe and Asia. The plant produces Polyurethanes, substances made from various chemicals that are commonly used in the Automotive, Appliance, Furniture and Footwear industries. These substances are characteristically “foamy”, and will typically form part of seats and steering wheels of cars, the insulating material of fridges and washing machines, mattresses and shoe soles.

Company A is one of the plants belonging to the region Europe. There are around 35 plants operating in Europe which are known in the company as System Houses. The System House in Johannesburg is the only one belonging to the Europe area that is not physically also on the European continent. At the end of 2011, a report done by the company’s Europe-division revealed that the South African plant had by far the lowest productivity rate in the whole region. Although this can mainly be attributed to the fact that they are the least developed as technology and automation are concerned, these findings were a cause of major concern for managers at the plant.

The Johannesburg plant consists of a production plant, as well as a warehouse for both raw materials and finished products. Raw materials and finished products are transported in 200kg drums with the use of forklifts. There are also designated hot rooms, ovens and cold rooms, in which some raw materials and finished products have to be stored to achieve or maintain their desired physical properties. There are 10 vessels that are used for the production of the polyurethanes. The plant uses approximately 360 different raw materials to make about 160 different final products. In a typical scenario, a worker will fetch the drums of raw materials from either the warehouse or the temperature-controlled storage areas, take them to the designated vessel, pump in the products with a specialized pump, start an automatic mixer within the vessel and let it run for the required time. When the time has elapsed, a person from the Quality Control Department will collect a sample of the product to test if it meets all the physical and chemical requirements. If the product passes the Quality test, it can be pumped out into new drums by the worker and sent to the warehouse for dispatch. If the sample does not pass, the chemists of the company have to decide what to add to the product and test it again until it passes all the Quality requirements.

The following problems at the plant were discovered by observation and communication with the operations manager:

1. **Warehousing**

The Warehouse of the plant is not managed optimally, which leads to stock inaccuracies and time lost when forklift drivers or production staff has to look for a product that is not in its designated place. Although in theory the company has a system according to which the warehouse should be managed, it very often does not translate into physical truths. The warehouse is divided into sections and bins, in which drums of product are stored. When a drum is taken from or put into a specific place, this information should be manually put into the SAP database. However, forklift drivers and production staff constantly complain about drums not being in their designated places. This is clearly a concern when trying to implement Lean, since flow is so often interrupted when staff members have to search for missing stock.

2. **Worker's Efficiency**

When a product is being made in a vessel, the operator responsible for that batch must not only load and unload the vessel, but is also supposed to stay at the vessel during production time and supervise the process in case a problem arises which requires the worker's attention. If the responsible worker is not at the vessel when something happens, he has to be looked for since accountability is very important in the plant. This is also time-consuming and the problem could worsen if not addressed immediately. If a worker does not supervise his process, chances that he does not unload the product immediately after the process is completed are high and time between batches is increased, leading to increased downtime of vessels. When taking samples of workers on the floor at random times, it was made clear that workers very seldom supervise the vessel they are responsible for during a production process. It is evident that they are not sufficiently supervised and that they need additional motivation to do their work properly. Another factor concerning the workforce is related to Trade Unions. The company's management has to explain themselves to Trade Unions often and to implement changes opposed by workers becomes extremely difficult. It is therefore absolutely necessary for workers to be willing to implement changes if they are going to be implemented successfully.

3. **Supply Chain Management**

Managing the Supply Chain at Company A is quite a challenging task, since their raw materials are shipped from overseas (mainly Germany and China) which causes lead times of three to four weeks. Production follows a make-to-order schedule, which makes it extremely difficult to plan for raw materials. Forecasts are made by salespeople based on a customer's order-history, but if an unexpected order arrives for a product and there are no raw materials, there is no way of getting them in time for the order to be filled. The Supply Chain team therefore tries to keep the stock of common raw materials to a specified level in an attempt to cater for such emergency situations. There is nonetheless no formal system to address the management of the Supply Chain, or a qualified person that forms part of the team.

4. **Quality**

One of the company's major concerns is that of quality. As discussed previously, whenever a batch of chemical has been finished, it has to be tested by a quality inspector, and only when it passes very specific requirements will it be allowed to be "dropped" into a container in which it will be shipped. The number of batches that pass the quality test the first time around is very small and poses a big concern for managers, since a significant amount of time and product is lost during the process of trying to repair the mixture until it has the required properties. This issue poses a big Lean challenge, since it causes two types of the seven wastes that Lean tries to reduce, namely that of defects and waiting. The flow of material in the plant is also hindered by this problem.

When comparing the South African plant with those in Europe, a few challenges that are unique to South Africa and are mentioned by Vermaak (2008) are encountered. The Supply Chain problems can easily be categorized under Vermaak's heading of "Distance" while the "Culture" and "Resistance by Trade Unions" challenges are also obvious in this plant when looking at the issues of worker's efficiency. As discussed earlier, the European plants of the company are highly automated which reduces human error in proceedings tremendously and clearly increases productivity. In South Africa, this is made difficult since firstly, the technology is not as advanced and secondly, automating the plant would mean a significant number of job losses for the company's workers. This can be categorized under Vermaak's Challenge of "Unemployment".

4.3.2 Company B: Auto Assembly Plant in Pretoria

The second company which was studied also forms part of an international car manufacturer and the plant is situated in Rosslyn, near Pretoria. The plant is divided into specific departments for assembling and painting the cars. Similar to the case of Company A, this company receives most of its parts from Germany, but delivers its products mainly to dealers within South Africa. The plant itself does not make its own forecasts, but assembles the cars as instructed by the headquarters which are also situated in Germany. A major problem for the Pretoria plant when compared to the plants in Europe is that of extremely long lead times. As an example, the delivery of an engine to the Johannesburg plant takes up to 8 weeks, while European plants can receive an engine within hours of placing the order.

When asked about their difficulties with implementing lean, the very clear and immediate response was that the plant is not operating stable enough for Lean to be implemented properly. Company B measures their Operational Stability in terms of variance in throughput times. A specific metric is used by the company to measure the difference in the planned release date of a car and the date it actually gets released. Although specific figures were not shared, the variance of this factor is clearly high. The other factors that this plant takes into account when considering their operational stability are “Sequence Adherence” and “Cumulative out of Sequence Cars”. Sequence Adherence reflects the number of cars that are not assembled according to schedule. For example, if there is a problem with one or many of the same car, they are taken out of production and cars that were supposed to be assembled afterwards are now shifted to the front of the production line, the cars that “jump” the queue are not adhering to the sequence. The Sequence adherence target is 95%, but this is not achieved at the plant. The actual number of cars that are assembled out of sequence, or more specifically in advance, before cars that should be assembled first, is reflected under “Cumulative out of sequence Cars”. While Company B has a target of below 20 for this factor, in extreme cases as many as 600 cars have been made in advance. These factors negatively influence the Operational Stability of the plant and flow is interrupted, which makes Lean implementation extremely difficult.

Another obstacle that the Pretoria plant faces is the conflicting views of managers regarding Lean. While on the one hand they want to achieve the cost-savings that Lean promises, they think of Lean as a “quick fix” and have given up on its implementation quite rapidly. The general notion of management is to never stop production unless it is absolutely necessary. This leads to the problems at hand not immediately attended to and overproduction of tock in advance. The European strategy to problems on the shop floor is to fix them before continuing, which saves more money and time than by producing a significant number of cars in advance. The

European plants are also constrained by their smaller workforce, whereas the South African plant will gladly use their excessive workforce to build cars in advance.

The challenges with Lean implementation that have been mentioned in Sections 4.1 and 4.2 and are most applicable to Company B are therefore summarised as:

- Operational Stability
- Distance
- Skills Shortage and
- Unemployment
- Rapid Lean Conversion

4.4 Summary of Lean Challenges

The studies that were done at the two different manufacturing companies in South Africa indicate that the gaps and challenges with Lean implementation that were identified through literature are indeed relevant. These companies face some challenges that are common around the world as discussed in section 3.1, as well as specific challenges faced by South African organizations described in section 3.2. Therefore, the challenges with Lean Six-Sigma implementation that will be addressed further in this report are summed up as follows:

- Operational Stability
- Rapid Lean Conversion
- Lack of Employee Involvement
- Distance
- Resistance by Trade Unions
- Unemployment
- Skills Shortage
- Culture
- Lack of Implementation know-how

To confirm the validity of this project, the factor “Lack of Implementation know-how” was added to this list. Since the aim of this project is to help guide companies with Lean implementation, it is important to know that companies do indeed see this as a challenge.

5. The New Lean Roadmap

The new lean roadmap is based on the original lean six-sigma roadmap and the House of Lean, as discussed in Section 3. The main goal of this roadmap is to address the challenges of Lean implementation specifically faced by South African manufacturing companies that were identified with the help of literature and case studies in Section 4. The new roadmap is presented in this section and the ways in which the original roadmap is adapted in an attempt to combat the challenges that South African manufacturing companies face when trying to implement Lean are explained.

5.1 Critical Factors

For the new roadmap to successfully address the identified Lean challenges 4 main factors were considered and the following section explains how they are incorporated into the design of the new roadmap.

5.1.1 The Foundation

When considering the House of Lean, the Foundation consists of Operational Stability and TPM. The concept that these factors form the foundation of the figurative house symbolizes that Lean implementation can not begin without them in place; much like a physical house hat can not be built without a foundation. Since Operational Stability was identified as one of the main issues faced by South African manufacturing companies, it is evident that the first step of the new roadmap should guide companies in achieving Operational Stability, a feature that is not included in the original roadmap. The challenge that was labeled “Distance” in the previous section will also be addressed in this first step of the new roadmap, since this issue is often the cause for organizations being unstable in terms of lead times and order fulfillments.

5.1.2 Selection of specific Lean Tools

Since no company operates in exactly the same way, a certain degree of uniqueness has to be included in the new roadmap. This is done by allowing managers to choose the Lean tools most suited for their company with the help of an Analytical Hierarchy Process (AHP).

5.1.3 Focus on People

The idea that people are the "heart" of an organization can be seen in the House of Lean, where the pillar of "Highly Motivated People" is placed in the middle of the house, indicating that this is the most important aspect of Lean implementation. The need for motivating and encouraging people to embrace change in the workplace of South African companies was addressed in Section 4 and all issues regarding the motivation of workers, including resistance by Trade Unions, were summarised as the Challenge of "Culture". This issue, as well as those of Unemployment and Skills Shortage, has to be considered intensively at every step of the new roadmap, since they are faced by most South African companies and may determine the success of Lean implementation.

5.1.4 Cyclic Approach

Both the original Lean Six-Sigma roadmap and the House of Lean represent the implementation of Lean as an ultimate goal or achievement, whereas in literature it is often described as a "way of life" and a workplace philosophy rather than a "quick fix" or a once-off success tool. The new roadmap will therefore be designed in a cyclical fashion, representing the idea that Lean implementation does not end at some point, but that it should be adopted as a continuous improvement mechanism. The steps of the new roadmap are hence divided into the 4 steps of the Plan-Do-Check-Act (PDCA) cycle with that will ensure Lean does not end, even when it has been successfully implemented.

5.2 The Steps of the New Roadmap

Before presenting the new lean roadmap graphically, the individual steps of this roadmap are explained in the following section. Although the roadmap aims at appealing to most South African manufacturing companies, some steps and tips are based on the assumption that these companies face the challenges identified in this report, similar to the companies on which the case studies were done.

5.2.1 The Foundation

The first step of the new roadmap is aptly called the Foundation, since the physical implementation of Lean can not begin without this step being completed. There are three main goals of this stage:

1. Operational Stability
2. Management Commitment
3. Decisions concerning Lean Tools

Operational Stability is usually measured or expressed differently by different companies. While some may use a metric concerning how many parts are produced out of sequence, others will use the number of perfectly fulfilled orders as a measure of their stability. For the purpose of this report, the factor that influences the operational stability of South African manufacturing companies the most is taken as distance, since it was identified as a major challenge of implementing Lean in this context. Along with distance comes the issue of forecasting, since the significant distance between suppliers and companies makes it practically impossible to order parts or materials only once they are needed. Therefore, it is strongly suggested that proper forecasting and inventory models are considered and put into place in order to reach operational stability. These recommendations may seem like they contradict the primary principles of Lean, since Lean aims at achieving no inventory at all which would also eliminate forecasting, but in situations like those of Companies A and B, it is merely impossible to only order the parts required for a product once the product is ordered. Since most manufacturing companies that are not completely Lean already will have at least one warehouse, this could be used as a substitute for a nearby supplier. The "supplier" should therefore run on proper inventory and forecasting models so that the risk of not having enough stock to supply the shop floor with is minimized. If only the Warehouse is run on principles of forecasting and inventory-control, the shop floor can run on a JIT basis, only taking the right amount of materials just when an order is placed. Appropriate Inventory models depend on certain parameters of specific companies, the most important being lead time and demand. Two types of inventory models will now be presented, since these may help in deciding when to order how many parts or materials for the warehouse, in an attempt to stabilize the operational environment of a company.

Inventory Models

The type of inventory model described in this section is known as a Fixed Order Quantity Model, and aims at calculating the reorder point as well as the right amount of parts or materials to order every time an order is placed. If the demand of a certain product is certain, this task is quite simple and a simple Economic Order Quantity (EOQ) model can be used. The following assumptions are made if the EOQ model is to be implemented:

1. A continuous, constant and known demand rate
2. A constant and known lead time
3. The satisfaction of all demand (no stock-outs)
4. A constant price or cost that is independent of order quantity or time (e.g. Purchase price or transport cost)
5. No inventory in transit (title of the goods only passes to buyer once they are received; no in-transit inventory carrying costs)
6. One item of inventory or no interaction between items
7. Infinite planning horizon
8. No limit on capital availability

If the demand is certain, there is no need for safety stock since this would only incur unnecessary inventory costs. The following variables are used to determine the EOQ model:

R = annual rate of demand or requirement for period (units)

Q = quantity ordered lot size (units)

A = cost of placing an order/setup cost (Rand per order)

V = value or cost of one unit of inventory (Rand per unit)

W= carrying cost per Rand value of inventory per year (% of product value)

S = VW = storage cost per unit per year (Rand per unit per year)

t = time (days)

TAC = total annual cost (Rand per year)

The total annual cost of one specific product can then be calculated using the following formula:

$$TAC = \frac{1}{2}QS + A\frac{R}{Q}$$

Since the aim of this model is to minimise costs without risking stock-outs, this formula is differentiated with respect to Q, set to zero and the EOQ is then calculated as follows:

$$Q = \sqrt{\frac{2RA}{S}}$$

The reorder point, given that demand is certain, is calculated simply by multiplying lead time by daily demand.

This Fixed Order Quantity model is very simple given the right conditions, however in practice the demand of a certain product is rarely so certain that this type of model can actually be used. If demand were always certain, a big distance between the supplier and the company would not pose such a big challenge, as the increased lead time would simply be incorporated into the EOQ calculations. Vice versa, if the distance between the supplier and the company would not be significant and lead time would not exceed a day, the uncertainty of demand would also not pose a big problem for lean implementation, since JIT could easily be accomplished by only ordering parts needed for a product once that product is ordered. However, most South African companies face the conditions of uncertain demand as well as a big distance between them and their suppliers, which makes the Fixed Order Quantity Model a little more complicated.

With the demand being uncertain for the next Fixed Order Quantity model, the following assumptions still apply:

1. A constant and known replenishment or lead time
2. A constant price or cost that is independent of order quantity or time (e.g. purchase price or transport cost)
3. No inventory in transit
4. One item of inventory or no interaction between items
5. Infinite planning horizon
6. No limit on capital availability

When demand and sales are uncertain, managers should emphasize the balance between the costs of carrying safety stock and of a stock out leading to lost sales. (Langley, Coyle, Gibson, Novack, & Edward, 2009) The reorder point under the condition of uncertain demand becomes crucial as safety stock has to be included in the level of inventory.

The Fixed Order Quantity model with the condition of uncertain demand will be explained using a product referred to as Product 101 of Company A as an example.

The exact demand of Product 101 is not known for calculations of this model, but certain assumptions and estimations have to be made in order to calculate the reorder point, order quantity and amount of safety stock to be used. First, a range of possible values for demand is established and a probability is assigned to each of these values. Using historical data of company A and assuming the demand follows a discrete distribution, the following table is drawn up:

Table 1: Probabilities of Demand for Product 101

DEMAND (units)	PROBABILITY
10	0.01
15	0.06
20	0.24
25	0.38
30	0.24
35	0.06
40	0.01

One unit is taken as 100kg of Product 101.

Using this information, a matrix is developed which displays the amount of product that the company would be "short" or "in excess" of considering the seven potential reorder points and the actual demand. This matrix can be seen in Table 2 below.

Table 2: Product 101 Shorts and Excesses of Reorder Points

	Reorder Points						
Actual Demand	10	15	20	25	30	35	40
10	0	5	10	15	20	25	30
15	-5	0	5	10	15	20	25
20	-10	-5	0	5	10	15	20
25	-15	-10	-5	0	5	10	15
30	-20	-15	-10	-5	0	5	10
35	-25	-20	-15	-10	-5	0	5
40	-30	-25	-20	-15	-10	-5	0

The following table displays the expected number of units "short" or "in excess" by multiplying the values from Table 1 with the probabilities associated with each reorder point.

Table 3: Probabilities of Product 101 Shorts and Excesses

	Reorder Points							
Actual Demand	**Probability**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
10	0.01	0	0.05	0.1	0.15	0.2	0.25	0.3
15	0.06	-0.3	0	0.3	0.6	0.9	1.2	1.5
20	0.24	-2.4	-1.2	0	1.2	2.4	3.6	4.8
25	0.38	-5.7	-3.8	-1.9	0	1.9	3.8	5.7
30	0.24	-4.8	-3.6	-2.4	-1.2	0	1.2	2.4
35	0.06	-1.5	-1.2	-0.9	-0.6	-0.3	0	0.3
40	0.01	-0.3	-0.25	-0.2	-0.15	-0.1	-0.05	0

The following variables are needed to calculate the TAC and optimal Q values for this model, additional to those mentioned for the simple EOQ model above:

e = expected excess in units

g = expected shorts in units

k = stockout cost in Rand per unit stocked out

G = gk = expected stockout cost in Rand per cycle

eVW = expected carrying cost in Rand per year for excess inventory

For the purpose of this example, the following values were calculated for Product 101 of Company A:

k = R50 per unit

V = R289 per unit

W = 25% of product value

VW = 0.25*289 = R72.25 per unit per year

R = 250 units per year (based on historical data)

A = R150 per order

$$Q = \sqrt{\frac{2RA}{VW}} = \sqrt{\frac{2(250)(150)}{72.25}} = 32.21 = 32\ units$$

In Table 3 the calculations of the above mentioned variables are carried out below the values displayed in Table 2.

Table 4: Calculation of Variables for Product 101

		Reorder Points						
Actual Demand	**Probability**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
10	0.01	0	0.05	0.1	0.15	0.2	0.25	0.3
15	0.06	-0.3	0	0.3	0.6	0.9	1.2	1.5
20	0.24	-2.4	-1.2	0	1.2	2.4	3.6	4.8
25	0.38	-5.7	-3.8	-1.9	0	1.9	3.8	5.7
30	0.24	-4.8	-3.6	-2.4	-1.2	0	1.2	2.4
35	0.06	-1.5	-1.2	-0.9	-0.6	-0.3	0	0.3
40	0.01	-0.3	-0.25	-0.2	-0.15	-0.1	-0.05	0
1.Expected excess per cycle (e)		0	0.05	0.4	1.95	5.4	10.05	15
2.Expected carrying cost per year (VW)		0	3.6125	28.9	140.8875	390.15	726.1125	1083.75
3. Expected shorts per cycle (g)		-15	-10.05	-5.4	-1.95	-0.4	-0.05	0
4. Expected stockout cost per cycle (G)		750	502.5	270	97.5	20	2.5	0
5.Expected stockout cost per year ($G\frac{R}{A}$)		5859.38	3925.78	2109.38	761.72	156.25	19.53	0
6.Expected total cost per year (2+5)		5859.38	3929.39	2138.28	902.61	546.4	745.64	1083.75

From Table 4 it can be seen that the lowest expected annual cost of R546.40 when inventory carrying costs and stockout costs are considered appears at the reorder point of 30 units (3000kg) of Product 101. This reorder point is therefore used for further calculations.

The formula for the TAC is now expanded from the simple model by adding safety stock cost and stockout cost, so that it becomes:

$$TAC = \frac{1}{2}QVW + A\frac{R}{Q} + (eVW) + \ (G\frac{R}{Q})$$

Differentiating this equation with respect to Q, setting it to zero and solving for Q then produces the equation:

$$Q = \sqrt{\frac{2R(A+G)}{VW}}$$

Using the calculated optimal reorder point of 30 units, Q is determined as follows for Product 101 of company A:

$$Q = \sqrt{\frac{2(250)(150+20)}{(72.25)}} = 34.29 \approx 34\,units$$

Therefore, Company A should order 34 units of this product every time 30 units are left in stock.

<u>Forecasting Model</u>

Although the EOQ model described in this section takes into consideration the uncertainty of demand, the value for demand still has to be estimated to a certain degree. In an attempt to forecast the amount of product that will be sold in a forthcoming period, the following forecasting model will be helpful. Again, the model will be illustrated using data of one of Company A’s products. This product is referred to as Product 520.

The model makes use of the least squares method to fit a trend line to historical data about Product 520’s demand. The expected value of forthcoming demand can then be estimated by the behavior of the trend line. The values of production of Product 520 (u_t in kg) for 11 time periods (t) are given in Table 6 below. For the purpose of further calculations, these time periods are numbered from t = -5 to t = 5.

Table 5: Production (ut) for Period t

t	u_t
-5	5960
-4	7989
-3	9232
-2	8012
-1	14947
0	8058
1	7491
2	18101
3	11107
4	21200
5	12482

These values are plotted on a graph displayed in Figure 13 and the best-fitting line is drawn through the values to represent the trend. The aim of this model is to get the equation of the line and thereby predict the demand of future time periods.

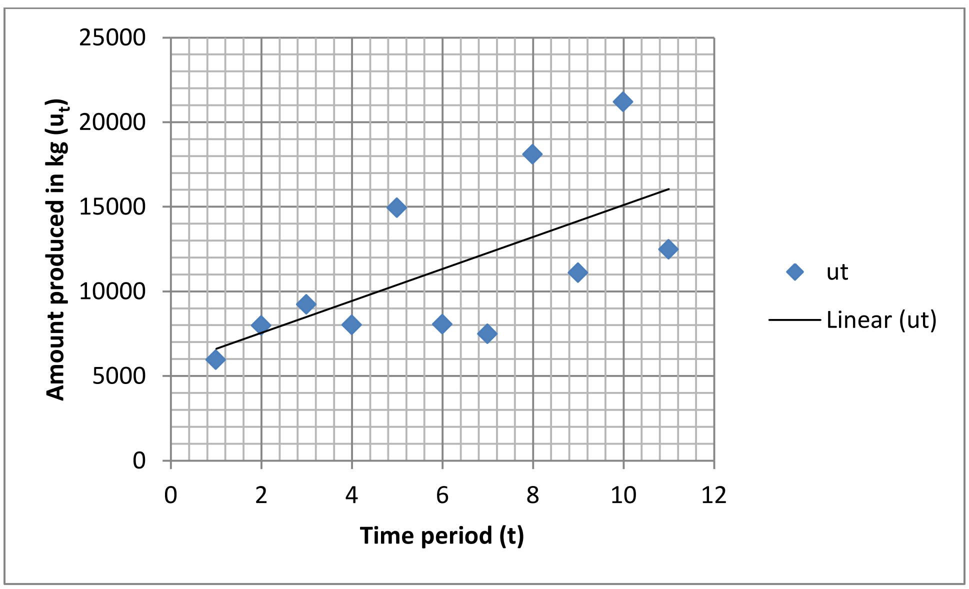

Figure 13: Scattergraph of Production Amount for Time Period t for Product 101

To calculate the future expected values of demand, the following equations are used:

1. $u_t = a + bt$
2. $\sum u_t = na + b \sum t$ (n = number of time periods)

3. $\sum tu_t = a\sum t + b\sum t^2$

Equation 1 is the simple equation for a straight line graph, and Equations 2 and three are used to calculate the numerical values for the variables a and b for this specific example. Table 6 includes all the values needed for these calculations.

Table 6: Calculated Variables for Production of Product 101

	T	u_t	t^2	tu_t
	-5	5960	25	-29800
	-4	7989	16	-31956
	-3	9232	9	-27696
	-2	8012	4	-16024
	-1	14947	1	-14947
	0	8058	0	0
	1	7491	1	7491
	2	18101	4	36202
	3	11107	9	33321
	4	21200	16	84800
	5	12482	25	62410
∑	0	124579	110	103801

Substituting the values into Equation 2 it becomes:

$$124579 = 11a + b(0)$$

$$124579 = 11a$$

$$a = 11325.36$$

Equation 3 becomes:

$$103801 = a(0) + b(110)$$

$$103801 = 110b$$

$$b = 943.65$$

Substituting these values into Equation 1 produces the trend equation of the best fitting straight line as:

$$u_t = 11325.36 + 943.65t$$

It is now quite simple to calculate the predicted demand for future time periods. For example, if the demand for time period 7 is required, a value of 7 is substituted for the variable t in the equation.

$$u_7 = 11325.36 + 943.65 * 7$$

$$u_7 = 17930.91kg$$

By approximating future demand with the help of forecasting models such as the one explained above, the task of inventory management is also made a little simpler. The value of R (rate of annual demand) that is used in the EOQ model although the demand for a certain cycle is uncertain can for example be calculated by analysing historical data and making use of the forecasting model.

<u>Total Productive Maintenance</u>

Along with the above mentioned factors to attain operational stability, a manufacturing company seeking to become Lean has to successfully implement TPM. For operational stability to be achieved, a company needs to have proper maintenance plans in place in order to reduce unpredicted breakdowns that increase downtime and interrupt production flow. It is therefore crucial to successfully implement TPM before starting Lean implementation.

Management Commitment also forms a crucial part of the Foundation. Without the commitment of managers to implement Lean, employees of lower levels will most likely not be encouraged to follow the Lean path either. Without being totally committed to Lean, managers will not be able to convince their employees of its benefits. The South African mentality to produce no matter what and that success is measured in production volumes, as observed at Company B, goes against Lean principles. Managers have to be made aware that producing unnecessary parts and/or products causes a lot of different kinds of waste, which directly translates into avoidable costs.

The aspects of management commitment that were addressed in step 1 of the original roadmap remain valuable for the new roadmap. Managers should strive to build and maintain positive relationships with their employees, by for example admitting to and apologizing for previous mistakes and wrongdoings. It is also important for managers to familiarize themselves completely with Lean tools and principles, either by self study or through outside training programs, depending on the company's budget and time constraints.

Decisions concerning Lean Tools also have to be made in this first step of the new roadmap. To assist managers in selecting the appropriate tools, an AHP has been designed to act as a decision-making tool regarding this issue.

To illustrate how the AHP should be performed by a company, this is done for Company A in the following example.

Step 1: Criteria Pairwise Comparison

The first step of the AHP is to rank the criteria (in this case the Lean challenges) according to the specific company. This is done by comparing all of the challenges with each other and assigning a value to each comparison to indicate which of the criteria is a bigger challenge to the specific company and by how much. The following scale is used to rank the comparisons:

When comparing Criteria A to Criteria B,

- 1=Criteria A is equally as challenging as Criteria B
- 3=Criteria A is slightly more challenging than Criteria B
- 5=Criteria A is strongly more challenging than Criteria B
- 7=Criteria A is very strongly more challenging than Criteria B
- 9=Criteria A is absolutely more important than Criteria B

The values assigned to the comparisons of each criterion with each of the other criteria are then put into a matrix, as shown below for Company A.

	A	B	C	D
A	1	1	8	5
B	1	1	7	7
C	0.13	0.14	1	3
D	0.2	0.14	0.33	1

Figure 14: Pairwise Criteria Comparison for Company A

The different challenges are identified as follows:

- A: Operational Stability
- B: Distance
- C: Culture
- D: Skills Shortage

The field highlighted yellow in Figure 13 displays the value for the comparison between A and C, or Operational Stability and Culture. Since Operational Stability is much more of a challenge to Company A than Culture, the value 8 has been assigned to this comparison. The inverse of this value indicates the comparison of Culture against Operational stability, as seen in the field marked green in Figure 13. Similarly, relevant values were assigned to each position in the matrix. The diagonal values of such a matrix will always all be 1, since these values show the ranking of a challenge against that same challenge.

The next step in the process of comparing the different challenges with each other is to construct the "Intermediate matrix". This is done by dividing the value of each matrix position by the sum of all the values of that row, as shown in Figure 14 below:

	A	B	C	D	Intermediate Matrix			
A	1	1	8	5	0.43	0.44	0.49	0.31
B	1	1	7	7	0.43	0.44	0.43	0.44
C	0.13	0.14	1	3	0.06	0.06	0.06	0.19
D	0.2	0.14	0.33	1	0.09	0.06	0.02	0.06
Sum:	2.33	2.28	16.33	16				

Figure 15: Intermediate Matrix for Pairwise Criteria Comparisons

Lastly, final weights are assigned to each criteria by calculating the average of each row in the Intermediate Matrix as follows:

Intermediate Matrix				C. Weights
0.43	0.44	0.49	0.31	0.42
0.43	0.44	0.43	0.44	0.43
0.06	0.06	0.06	0.19	0.09
0.09	0.06	0.02	0.06	0.06

Figure 16: Criteria Weights for Company A

The final ranking of Lean challenges faced by Company A can now be seen in the following chart:

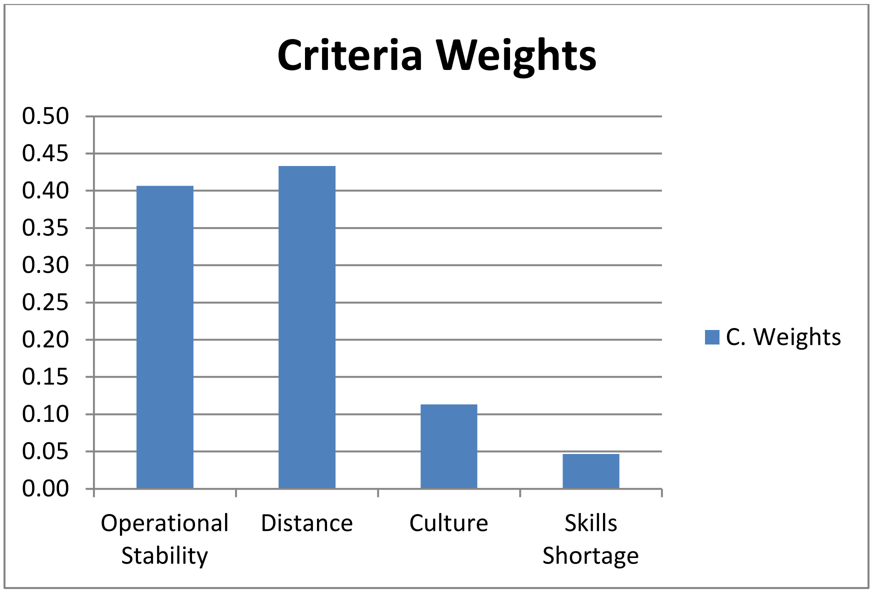

Figure 17: Bar chart of Final Criteria Weights for Company A

As can be expected, Distance is shown to be the biggest challenge for company A, closely followed by Operational Stability.

Step 2: Alternative Pairwise Comparison

After the final criteria weights have been determined, a similar comparison-procedure has to be done for the different alternatives (in this case the Lean tools). Each alternative is compared to each other alternative with respect to each criterion. This means that 4 different matrices need to be constructed.

The first matrix for Company A is shown below and it represents the comparisons between all of the alternatives with respect to Operational Stability.

Alternative Pairwise Comparison wrt OPERATIONAL STABILITY						
	6σ	**5S**	**VSM**	**JIT**	**A3**	**Leveling**
6σ	1	7	7	5	7	1
5S	0.14	1	3	3	3	0.11
VSM	0.14	0.33	1	3	5	0.11
JIT	0.33	0.33	0.33	1	1	0.11
A3	0.14	0.33	0.2	1	1	0.11
Leveling	9	9	9	9	9	1
Sum:	10.75	17.99	20.53	22	26	2.44

Figure 18: Alternative Pairwise Comparison with respect to Operational Stability for Company A

The scale for assigning values to each alternative comparison is similar to that of the criteria comparisons, namely:

1=Alternative 1 is equally as valuable as Alternative 2 in combating Challenge X

3=Alternative 1 is slightly more valuable in combating Challenge X than Alternative 2

5=Alternative 1 is strongly more valuable in combating Challenge X than Alternative 2

7=Alternative 1 is very strongly more valuable in combating Challenge X than Alternative 2

9=Alternative 1 is absolutely more valuable in combating Challenge X than Alternative 2,

where Challenge X represents the Criteria with respect to which the Alternatives are being compared.

In Figure 17, the field highlighted orange represents the comparison between alternatives 1 and 5, or Six Sigma and A3 Management with respect to Operational Stability. The value 7 indicates that Six Sigma is a much more powerful tool in combating the challenge of operational stability than A3 Management, since the main focus of Six Sigma is to reduce variability and produce more stable processes.

The rest of the matrix is filled in similar to the matrix of the criteria comparisons in Section 3.2.1, and the steps that follow are identical to those of the criteria comparisons. The Intermediate Matrix is constructed and finally the alternative weights are determined. This procedure is shown for the Alternative Comparisons with respect to Operational Stability below:

Intermediate Matrix						Alt. Weights
0.09	0.39	0.34	0.23	0.27	0.41	0.29
0.01	0.06	0.15	0.14	0.12	0.05	0.09
0.01	0.02	0.05	0.14	0.19	0.05	0.08
0.03	0.02	0.02	0.05	0.04	0.05	0.03
0.01	0.02	0.01	0.05	0.04	0.05	0.03
0.84	0.50	0.44	0.41	0.35	0.41	0.49

Figure 19: Alternative Weights with repect to Operational Stability for Company A

This procedure is followed for every Criteria/Challenge until Alternative Weights for every Lean tool have been established with respect to every Challenge.

Finally, the alternative weight for each Lean tool is multiplied with the criteria weight of each challenge, and the sum of these will produce the Final Alternative Weight, as indicated by the following formula:

$$Final\ Weight\ for\ Alternative\ i = \sum_{x=1}^{4} (Criteria\ Weight\ x)(Alternative\ Weight\ i)$$

The Final Alternative Weights for the various Lean Tools in Company A were calculated in this manner and are graphically shown below:

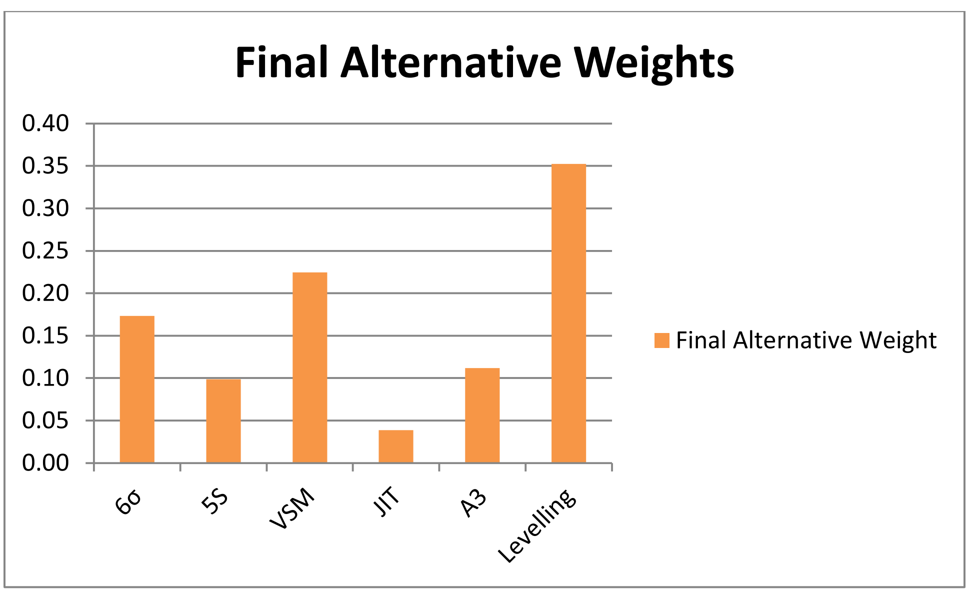

Figure 20: Bar Chart of Final Alternative Weights for Company A

As can be seen from this chart, the tools Leveling, VSM and Six Sigma are most valuable for Company A and the focus should be kept on these when implementing Lean.

While the first part of the AHP is unique for every company (by the ranking of challenges), the comparison matrices for the alternatives will remain the same, since these comparisons depend only on the challenges, and not on a specific company.

5.2.2 Employee Motivation

The second step of the original Lean Six-Sigma roadmap is called “Communication Channels” and deals with communicating effectively with employees. This is clearly an important concept when trying to implement Lean, but does not serve alone as the second step for the new roadmap. As shown by the House of Lean and discussed in Section 5.1.3, the focus on employees and their motivation is extremely important when trying to implement any new idea or change. The entire second step of the new roadmap is therefore dedicated to addressing the people-issues with Lean implementation. Effective Communication certainly plays an important role in keeping employees content and motivated, and thus will remain a part of the second step.

1. **Communication Channels:** Mehta (2005) indicates that effective communication with employees is extremely important when implementing Lean. Employees should be aware of every step that is taken by the company towards becoming Lean from the beginning. A common reason why people resist change in the workplace is the fear of losing their jobs. It should therefore be communicated right from the beginning that the implementation of Lean will not directly cause any workforce to be retrenched. This point is particularly important since many organizations minimise their workforce when implementing Lean to reduce unnecessary manpower and costs. As discussed previously however, the new roadmap does not aim at retrenching employees, since this is highly unethical in a country with large unemployment figures. “Extra” workforce should rather be redirected to other tasks in the company when their work becomes redundant. This issue is addressed further in Section 5.2.3. The establishment of

effective communication channels between management and employees should work in both ways. Not only should management communicate the actions of the company to the employees, but the employees should also report on shopfloor activities to managers. The probability of workers reporting on success as well as errors, problems or failures (which is extremely important information when implementing Lean) is increased when they know management also communicates with them. They should therefore be encouraged to report to management, even if it is to report a problem or mistake. If workers feel intimidated by management, some problems are sure not to be reported. For constant, effective communication and reporting of shopfloor activities "monthly meetings are good but a daily update is invaluable". (Mehta, 2005) The overall performance of a company is also valuable information to convey to workers, since this will establish a sense of achievement when the company is doing well and motivation to work harder when it is needed. If people do not know what their work accomplishes in the bigger picture, they will be less motivated to perform well. Mehta (2005) suggests displaying the performance of a company in some visual way on the shopfloor in order for employees to constantly be aware of it. A light system resembling a traffic light can be placed on the shopfloor, where green indicates good performance, orange shows average performance and red warns of poor performance.

2. **Cultural Aspects:** The need to address cultural aspects when implementing Lean has already been identified in this report. The success of Lean in a company such as Toyota is said to depend significantly on the Japanese culture of team-orientation. The mantra of "Ubuntu" under the black South African population resembles the Japanese team spirit and should be encouraged in the workplace. Workers should be asked about his aspect of their culture and how they think it could be integrated into the workplace. The typical South African labour force tends to be quite demanding and reward-driven. News reports about strikes in all sectors because of high demands are seen alarmingly often, which illustrates this point quite clearly. Hence it is important to motivate employees in a way that does not necessarily promise more money or bigger rewards, although the "What's In It For Me" factor also described by Mehta (2005) must be

considered in motivating people to perform well. It is invaluable to demonstrate that the company's overall achievement reflects the achievements of all the workers and that their effort is valuable to the company as a whole. Subtle awareness of benefits such as job security and fair salaries, which are not common in South Africa, when the company is performing well, can be utilized in motivating workers. It is also beneficial to give workers as much sense of accomplishment as possible. Since the workers in question are unskilled labourers of which the absolute minority have degrees or even high school diplomas, the sense that they can contribute to a cause with their knowledge is of great value to them. Their knowledge is based on the hands-on experience in their field of work and the opinion of what will work for their specific area is in fact best made by them. Even if a manager or supervisor has a specific idea of how to address a certain problem, he or she should try to "plant" this idea in the worker's head to make it theirs, since this will give them the feeling of accomplishment rather than being forced to employ management's plans. Incentives can also be considered, but rather in the form of performance incentives as opposed to monetary rewards. Programmes such as "worker of the month" or "Lean champion of the month" can be implemented to further motivate employees.

3. **Trade Unions:** Since the general opinion of trade unions in South Africa will determine the individual workers' actions to a large extent, it is crucial to involve them in communications too. If, for example, a trade union of a specific sector decides to strike, the workers that strike will not only stay away from work, but also prevent workers who do not feel the need to strike from going to work by violence and intimidation. Any major change like Lean implementation and job recreation should therefore also be discussed with or at least communicated to the appropriate trade union(s) through their representative(s). The trade unions must also understand that implementing Lean will not directly cause job losses, and that workers are valued at the company. The implementation of any major change without first notifying the relevant trade union(s) should be avoided at all cost. If the trade unions understand the benefits and rewards

of Lean to the company and therefore any employee of the company, the probability that workers will resist the change that Lean brings with it is decreased.

4. **Organisational Framework:** A key aspect of Lean is to divide the workforce into teams. At this stage of the new roadmap, teams are formed and assigned to specific lines or departments within the company. It is important for workers to be involved in the formation of teams, since forcing them into teams in which they do not feel comfortable in will cause low morale and motivation. The teams will be responsible for the application and success of Lean in their specific unit. The Lean training of teams as well as team leader allocation is discussed in the next section. The roles and responsibilities of supervisors and managers regarding Lean must also clearly be identified and documented.

The first two steps of the new Lean roadmap are categorized as the "Plan" stage of the PDCA cycle as they deal with preparing management and employees before Lean is physically implemented.

5.2.3 Training

The original Lean Six-Sigma Roadmap divides training into two phases: "Basic Training" and "In-Depth Training", with the phases "Organisational Framework" and "Implementation Plan" between them. For the new roadmap, these two aspects are covered to the needed extent in the first step, since they fall into the planning stage of the PDCA cycle. The two different training phases of the original roadmap will therefore be combined for the new roadmap in order to simplify the physical map.

The third step of the new roadmap is the stage at which employees are properly trained in Lean philosophies and the tools that will be used by their specific company. Although the options of management training employees themselves as well as providing training through an outside programme exist, it is highly recommended that managers face this task themselves. External experts might have a more detailed knowledge of Lean itself, but managers have a better understanding of how the company functions and therefore how Lean will best be integrated.

The input of workers should also be encouraged in these training sessions, since they will have the best idea of how well something will work given their specific area of work.

The high South African unemployment rate and the worker-friendly labour laws make it extremely difficult to lay off employees and often cause companies to be overstaffed. However skilled workers are not that prominent and an imbalance between skilled and unskilled workers is created. The training of employees for the implementation of Lean can address two of the identified challenges for South African companies: Skills Shortage and Unemployment. Instead of the traditional approach to lay off employees when they become redundant through Lean, these “extra” employees can be trained for Lean purposes. Specific workers can be trained by management or through an external training programme so that at least one worker per team is practically an expert in the Lean tools that were decided on by management and are appropriate to that team’s area of work. Such Lean experts will then be responsible for keeping up to date with the Lean techniques, reporting successes and failures of the Lean tools to management and ensuring that the Lean implementation is an ongoing process that does not fade away with time. Since these “experts” will be one of the workers rather than a manager who might be seen by as a strict authoritarian, they could be less resistant to the orders given to them. The experts will also be made responsible for tasks that are exclusively linked to Lean implementation, such as visual management and the physical layouts of A3’s and VSM maps.

The principles of the third pillar of the House of Lean called “Jidoka” are included in this step of the new roadmap. This entails installing a system that stops production completely when a problem occurs with any part of the production line until that problem is completely resolved. If technical faults or other problems causing defects of the product do not cause the line to stop producing, the problem will not be attended to as quickly as when production stops and places pressure on the reaction time. Both employees and managers must be trained to successfully make use of such a system.

5.2.4 Pilot Implementation

Depending on the structure of the specific company, a pilot production line or department is selected in this step for the selected Lean tools and implementation plan to be tested on. The original roadmap implies that VSM and 5S should be implemented in this step, but since it is up to the company to decide on which Lean tools to use in the first step of the new roadmap, those tools will be implemented. Although a specific time frame is not given for this roadmap, the pilot implementation should be allowed enough time to start showing results. This step serves as an opportunity for management to observe the results of the selected implementation plan on a small scale before implementing it in the whole company. As suggested by Mehta (2005) in the original roadmap, the following items should be included in the pilot line implementation as they must feature for every line or department once the company-wide implementation takes place:

- Team building
- Root Cause Analysis
- Activity Charts

Team building is important in that it creates positive dynamics between team members and simplifies the task of working together toward a common goal. Root Cause Analysis is done for a single line or department to identify the causes of problems faced by that specific unit. The Root Cause Analysis of the pilot implementation will also be useful to identify problems that could be faced by other departments and address these prior to the company-wide implementation.

Steps four and five of the new roadmap make up the “Do” stage of the PDCA cycle into which all steps are categorized.

5.2.5 Check

The original Lean Six-Sigma roadmap only briefly expresses the requirement of establishing metrics to measure the performance of the company once the established Lean implementation has been completed. At first, only metrics for the pilot line or department can be measured, but as the PDCA cycle repeats itself, the remaining departments are also measured according to certain metrics.

The following table is an adaptation of the original roadmap's assessment sheet displaying only metrics that are relevant to the new roadmap. This assessment sheet is used to monitor the company's performance regarding the Lean implementation.

<table>
<tr><th rowspan="2">Phase</th><th rowspan="2">Milestones achieved</th><th colspan="7">Scale</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td rowspan="7">FOUNDATION</td><td>Operational stability has been achieved</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>All members of management are committed to Lean philosophy</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Management has detailed understanding of Lean principles and tools</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Relevant Lean tools have been chosen</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>TPM has been successfully introduced</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Organisational Framework has been defined</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Implementation plan is defined and thoroughly understood</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="7">EMPLOYEE MOTIVATION</td><td>Management has good relationship to employees</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Employees know how well company is performing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Communication with Trade Union(s) is effective</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Employee motivation is high</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Meetings between management and employees are held frequently</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Incentive plans have been considered and implemented</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Overall worker morale is high</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">TRAINING</td><td>Lean team leaders have been assigned, trained and are performing well</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Workforce has been distributed according to Lean needs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Lean training has been provided to all employees</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Workers have been trained for "Jidoka"</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Phase	Milestones achieved	Scale						
		1	2	3	4	5	6	7
PILOT IMPLEMENTATION	Lean tools are successfully used on pilot line							
	Pilot team is working together successfully							
	Team building has been done							
	Root Cause Analysis and Activity charts are in place							
	Results of pilot implementation are available and useful							
CHECK	Metrics are relevant company's Lean goals							
	Metrics are confirmed regularly to monitor progress							
	Visible involvement of managers in monitoring metrics							
COMPANY-WIDE DEPLOYMENT	Setup time reduction is observed							
	Idle time is reduced							
	Pull production is in place							
	Cells are well deployed							
	Flow is continuous							
	Work is adequately balanced between units and employees							

Figure 21: Assessment Sheet for New Roadmap

As Mehta (2005) suggests for his roadmap, every criterion displayed in Figure 21 should be awarded at least a value of six for it to have reached an acceptable level and before continuing with the implementation. The metrics shown for the last step of the new roadmap called "Company-wide Deployment" represent the ultimate Lean goals for manufacturing companies. As the PDCA cycle repeats itself the relevance of some metrics will change, such as those assigned to the "Pilot Implementation" step. These metrics are then assigned to all departments individually.

5.2.6 Company-wide Deployment

The sixth and final step of the new roadmap is very similar to the last phase of the original Lean Six-Sigma roadmap and also called Company-wide Deployment. At this stage, the planning, training, preparing and testing that was done in the previous steps is used to finally implement Lean throughout the entire company. The pilot implementation serves as a "prototype" for other lines or departments, and the tools and techniques that were employed for the pilot implementation are now spread to every remaining line or department. Teams established during the planning phase are employed to their assigned line or department throughout the company. Problems that were observed with the pilot line implementation must be addressed and the solutions incorporated into the implementation for the remaining lines. Management and team leaders should be readily available at this stage to guide all teams and encourage smooth implementation. Since this step of the new roadmap also represents the “Act” phase of the PDCA cycle, the causes for problems and faults discovered through the root cause analysis carried out in the “Pilot Implementation” step and the metrics that were assigned values below 7 in the “Check” phase have to be addressed.

Once Lean has been implemented for an appropriate amount of time, the Lean achievements concerning reductions of lead times, inventory, warehouse and manufacturing space requirements, setup times and improvements on operational reliability and quality should begin to materialise.

5.3 Presentation of the New Roadmap

A summary of the new Lean Implementation Roadmap is presented in this section, followed by the graphical presentation of the roadmap and a few notes on its utilization.

5.3.1 Summary of Roadmap Steps

Phase	Steps	
PLAN	1. Foundation	Operational Stability, including Inventory Management and Forecasting
		TPM
		Management Commitment, including decision regarding Lean tools
	2. Employee Motivation	Communication Channels
		Cultural Aspects
		Trade Unions
		Organisational Framework, including establishment of teams

Phase	Steps	
DO	3. Training	Lean Tools
		Team Leaders
	4. Pilot Implementation	Team Building
		Root Cause Analysis
		Activity Charts
Check	5. Check	Assessment Sheet
Act	6. Company-wide Deployment	Lean Implementation
		Correction of pilot line problems

Figure 22: Summary of New Roadmap Steps

5.3.2 Graphical Presentation of the New Roadmap

The new Lean roadmap with its basic steps categorized into the stages of the PDCA cycle is shown graphically in Figure 23.

5.3.3 Additional Notes regarding Utilisation of the New Roadmap

Unlike the original Lean Six-Sigma roadmap, the new Lean Roadmap does not provide any time frames in which individual steps need to be completed. It is more important to complete one step of the roadmap before moving on to the next than completing it in a certain time period. Since Rapid Lean Conversion was identified as one of the challenges of Lean implementation, this aspect of the old roadmap is deliberately left out of the new roadmap. It should however be noted that the completion of a full cycle of the roadmap will take up to several years. Once the initial cycle has been successfully completed, the focus is returned to the first step of the roadmap in order to achieve continuous improvement of Lean efforts and ensure that the Lean philosophy is not abandoned. The steps of the new roadmap presented in figure 23 are specifically aimed at the first completion of the PDCA cycle. Thereafter, some of the steps will be adapted or excluded by management; however the basic structure of the cycle remains unchanged.

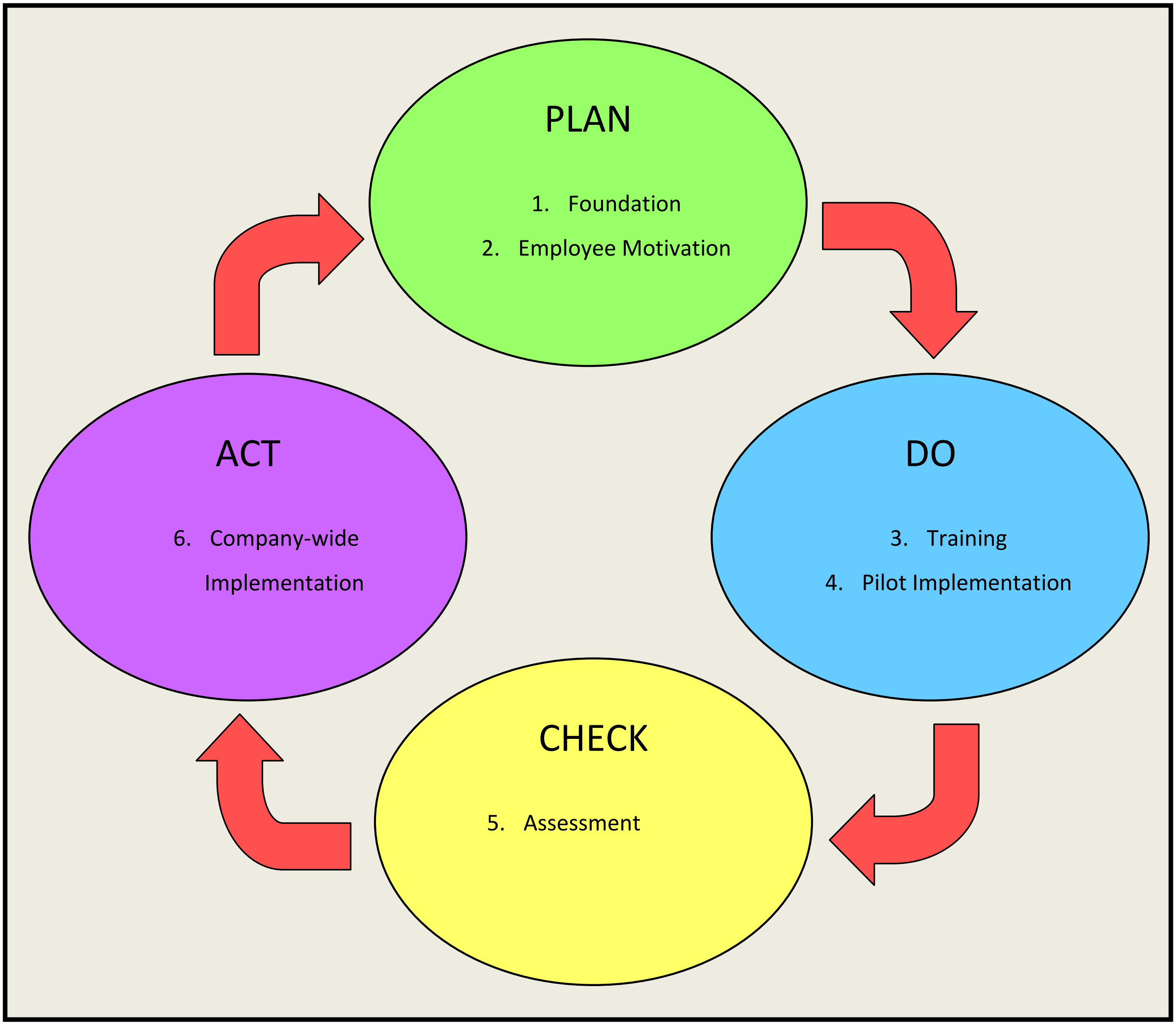

Figure 23: The New Lean Roadmap

6. Conclusion

This report presents the steps that have been completed as part of a project to develop a Lean Implementation Roadmap for South African manufacturing companies in order for them to reap the benefits of Lean that are observed internationally more frequently. An existing roadmap for international companies, along with other supporting literature was used as a template for the design of the South African roadmap. Based on challenges faced by South African manufacturing companies, as identified through literature and case studies, certain aspects were included or removed from the original roadmap to address the challenges and adapt it to the South African manufacturing environment. The steps involved in the new roadmap were explicitly described and divided into the phases of the PDCA cycle as follows:

- PLAN
    1. Foundation
    2. Employee Motivation
- DO
    5. Training
    6. Pilot Implementation
- CHECK
    6. Assessment
- ACT
    7. Company-wide Implementation

Finally the new Lean roadmap was presented graphically to visually represent the different phases and individual steps needed for Lean implementation in a South African manufacturing company.

7. References

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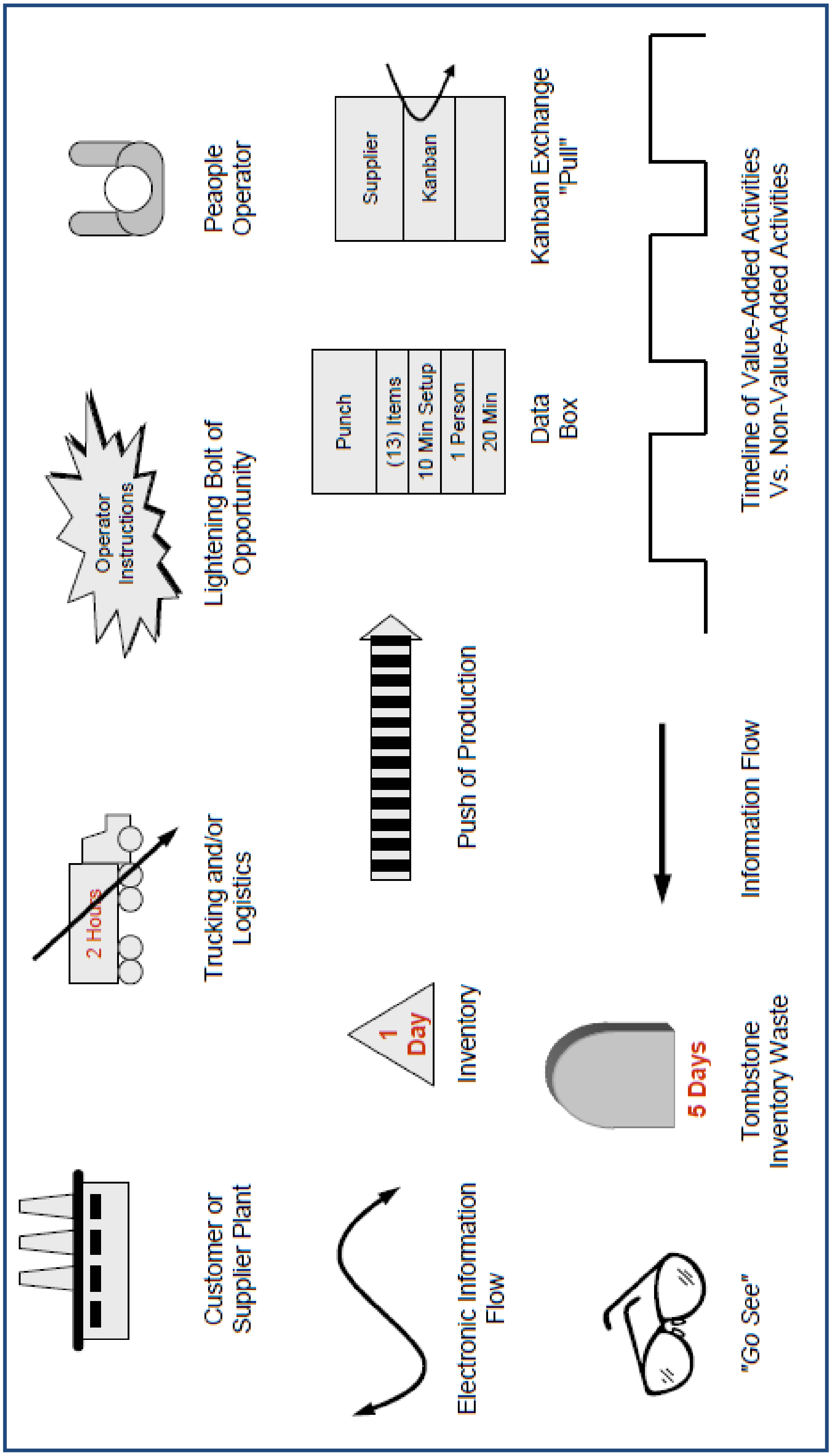
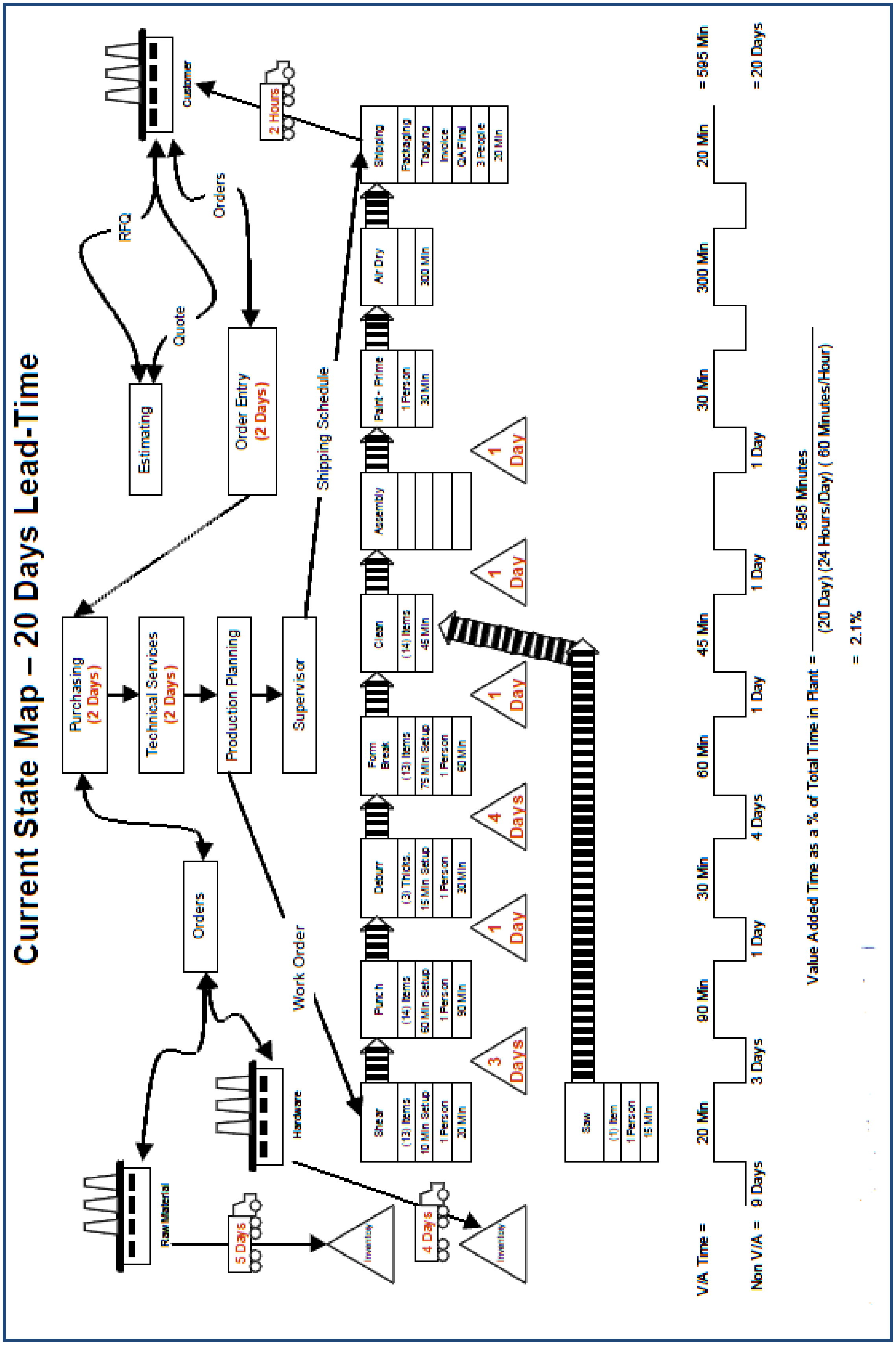
8. Appendix

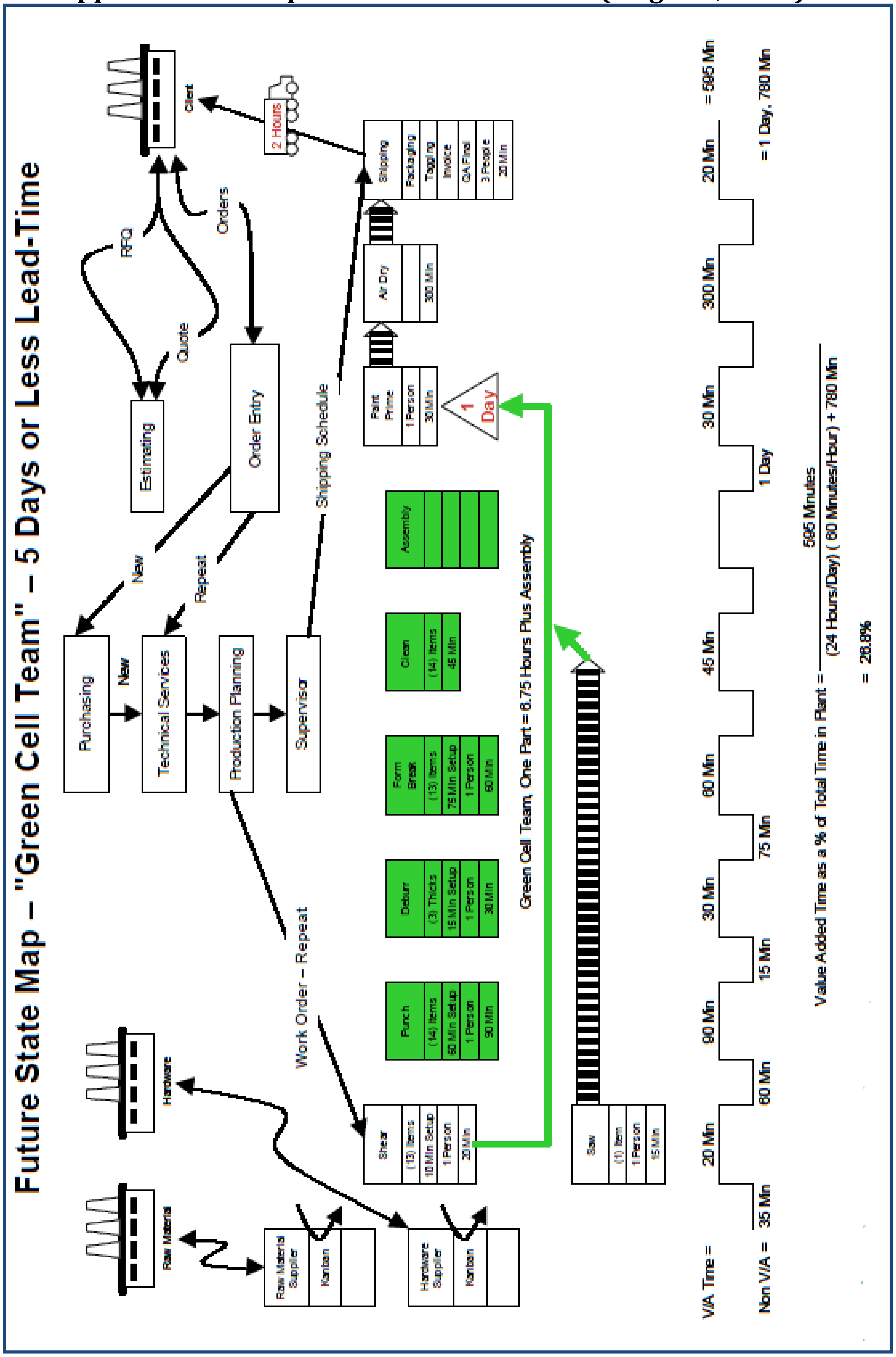
8.1 Appendix A: List of Icons typically used for VSM (Magnier,2003)



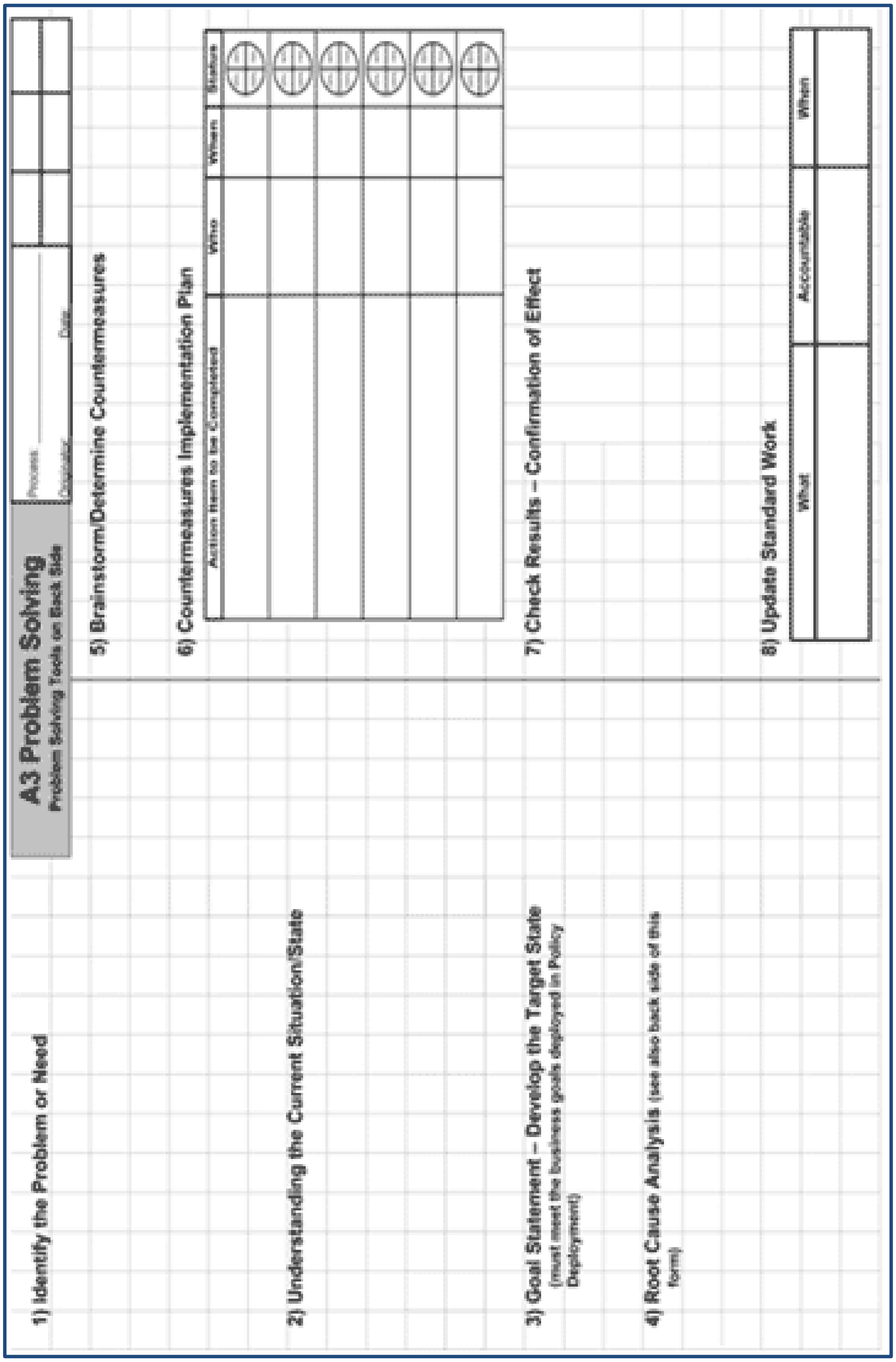
8.2 Appendix B: Example of a current state VSM (Magnier, 2003)



8.3 Appendix C: Example of a future state VSM (Magnier, 2003)



8.4 Appendix D: Example of an A3 Template (Rubrich, 2012)


A3 Problem Solving

Problem Solving Tools on Back Side

Process

Originator

Date

1) Identify the Problem or Need

2) Understanding the Current Situation/State

3) Goal Statement – Develop the Target State (must meet the business goals deployed in Policy Deployment)

4) Root Cause Analysis (see also back side of this form)

5) Brainstorm/Determine Countermeasures

6) Countermeasures Implementation Plan

Action Item to be Completed	Who	When	Status

7) Check Results – Confirmation of Effect

8) Update Standard Work

What	Accountable	When

8.5 Appendix E: Assessment Sheet for Original Lean Six-Sigma Roadmap

Phases	Overall Description of Phase	Detail milestones to be achieved in the phase	Scale 1	2	3	4	5	6	7
Phase 1 Management commitment	Clear statement of purpose	Management is very familiar with lean six-sigma philosophies and knows the extent of commitment that would be necessary to embark on the lean path.							
		Management has made a commitment through a open letter prominently displayed, declaring its intent of pursue and stick to the lean six-sigma path							
		Management has shown a commitment to improve and stregthen relationships with employees							
	Visible signs of commitment	Management reads the open letter at the beginning of each lean six-sigma meeting							
		Management has clear visible involvement in all lean six-sigma meetings							
Phase 2 Communication channels	Information channels	The employees know each day how well the company did							
		Bulletin boards in strategic places to disseminate information							
	Motivational channels	Management conducts weekly/monthly meeting to inform employees and motivate them							
Phase 3 Basic training	Company trainers available	The company has home-grown trainers who will be able to train the employees							
	Lean principles	Training has been conducted in basic lean principles for all the employees							
	Six-sigma philosophy	Training has been conducted in basic six-sigma philosophy for all the employees							
	Team training	Training has been conducted in team building amongst all the employees							
	Product oriented training	Training has been conducted in design for manufacturing, design for assembly and standardization							
Phase 4 Organizational framework	Lean six-sigma organization created	Lean six-sigma steering committee established							
		Lean six-sigma champions identified							
		Lean six-sigma coordinators (black-belts) identified							
		Role descriptions for champions and coordinators created							
	Metrics	Lean six-sigma initial metrics identified							
		Metrics articulated and published							
		Visible involvement of top management in creating and monitoring metrics							
	WIIFM	"What is in it for me" explained to the employees							
		Incentive and gainsharing plans considered and implemented							

Phases	Overall Description of Phase	Detail milestones to be achieved in the phase	Scale 1	2	3	4	5	6	7
Phase 5 Implementation plan	Combined lean six-sigma plan	A comprehensive combined lean six-sigma has been developed							
Phase 6 Training in tools	5-S	Training for the relevant teams has been carried out in 5-S housekeeping							
	Value stream mapping	Training for the relevant teams has been carried out in value stream mapping of processes							
	Conducting kaizens	Training for the relevant teams has been carried out in the conducting of kaizens							
Phase 7 Pilot implementation	5-S of a pilot line	Pilot implementation of 5-S for a production unit has been completed							
	VSM of a pilot line	Pilot implementation of a value stream mapping session for a production unit has been completed							
Phase 8 Conducting kaizens	TPM	Based on the results of the value stream mapping session of the pilot line kaizen activities to demonstrate the following within the company have been carried out to act as a model for the others following the lean six-sigma journey to emulate							
	Setup reduction								
	Pull production								
	Root cause analysis								
	Standard work								
	Gage R&R								
	SPC/Pre-process control								
Phase 9 VSM other lines		VSM of other lines after creation of teams for lean six-sigma implementation in other parts of the company have been carried out							
Phase 10 Company-wide implementation	Well deployed cells	Company-wide deployment of lean six-sigma with special significance to the deployment of cells, work balancing amongst the various cells and employees, the continuous flow of product using pull systems and synchronized cells to optimize flow have been deployed							
	Work balancing								
	Continuous flow								
	Synchronized cells								