INVESTIGATING THE BENEFITS OF USING SELECTED LEAN TECHNIQUES AT A SOUTH AFRICAN EXHAUST MANUFACTURER – A CASE STUDY

BY

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PORT ELIZABETH

DECLARATION

I declare that:

INVESTIGATING THE BENEFITS OF USING SELECTED LEAN TECHNIQUES AT A SOUTH AFRICAN EXHAUST MANUFACTURER – A CASE STUDY

is my own work and all sources used or quoted have been indicated and acknowledged by means of complete references. I have not previously submitted this treatise for a degree at another university.

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A M Louw Date

ABSTRACT

This study investigates the implementation of supermarket-based scheduling of parts at a South African exhaust manufacturing plant.

The study firstly investigates the requirements the manufacturer had to contend with in ensuring a valuable contract was won. The nature of the contract is such that it warrants building of a new facility. The design of the facility and the manufacturing processes is of importance as some Lean techniques are employed during these early stages.

The research takes the form of a case study and data is collected mainly through interviews with staff, but also from direct observations on the shop-floor.

Interviews were conducted with:

- key project leaders responsible for the original design and commissioning of the facility;
- production managers and technical staff currently operating the plant; and
- shop-floor personnel involved in daily production and logistics operations within the plant.

The as-built facility and procedures are compared with literature found on the topic of Lean manufacturing. Various findings are recorded, both on conforming to and not conforming to typical Lean theory.

Potential changes are suggested in the following areas:

- a Pull strategy is proposed to coincide with the appointment of a so-called pacemaker station;
- a pacemaker would need to be further supported by a production leveling strategy;

- although quality delivered to the customer is reported as very high, potential improvements are still possible by introducing an ‘at source’ approach to reduce rework; and
- finally, a Total Productive Maintenance (TPM) program will serve to reduce downtime even further.

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- The staff and management of the particular organisation used in this study. Their support and assistance have been fundamental to this research. Based on prior agreement at the request of the organisation's management, the organisation and all individuals will remain anonymous. All details pertaining to the specifics of the organisation will be kept confidential.
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION AND PLAN OF STUDY

1.1 INTRODUCTION

The Japanese Lean Manufacturing guru, Taiichi Ohno (Ohno 1982: 73-74) explains how he and members of Toyota's production management team had discovered a new application for something, already in use in the US, by 1952. The concept was that of the supermarket. In a supermarket the customer dictates what he wants and how much/many of it he needs, based on his personal situation and budget. He then draws this only and the shop-manager restocks the shelf. This method of shopping was foreign to the Japanese who were used to a form of home-delivered shopping, yet Ohno recognised the supermarket as a low inventory strategy with cost saving opportunities.

The same practise was implemented by a catalytic converter manufacturer in Rosslyn, close to Pretoria, South Africa, in 2005. The manufacturer was committed to supply its customer with the correct parts and quantities in the precise sequence they needed it in. In addition to this, they had to also comply with specific quality and production related requirements, such as minimum inventory levels, delivery frequency and presentation methods, to name a few.

This research investigates the manner in which the manufacturer achieved the set objectives and documents the resulting success in an effort to find solutions that could be applied by other organisations to achieve similar objectives.

1.2 RESEARCH PROBLEM

The following statements serve as basis for defining the research problem:

- Manufacturing organisations need to achieve customer satisfaction objectives as well as business objectives in order to remain competitive.
- Lean manufacturing techniques have been proven to lead to superior results in production related industry in terms of both customer and business objectives.

The resulting research problem has been formulated as follows:

Are there benefits in the application of selected Lean manufacturing techniques to achieve the desired scheduling results at a Rosslyn based exhaust manufacturer?

1.3 SUB PROBLEMS

The following sub-problems have been identified to assist in solving the above main problem:

- What does literature reveal about the philosophy and practices of Lean manufacturing?
- What does literature reveal about the use of supermarket scheduling systems?
- How was this project initiated and implemented at the Rosslyn factory?
- How successful was the implementation, in terms of meeting the demands of the customer?
- What barriers and obstacles were encountered and had to be overcome?
- What was learnt as a result of implementing a supermarket approach?
- What recommendations can be proposed?

1.4 LITERATURE OVERVIEW

The literature review will focus on the implementation and application of:

- Lean manufacturing in general,
- Kanban, Lean scheduling and supermarket systems
- Operations management and customer focus as a business strategy.

Womack, Jones and Rice were the first authors to present Lean manufacturing to the world in *The machine that changed the world (1990)*. However Womack and Jones only presented the principles of Lean manufacturing in their subsequent book *Lean Thinking*, (1996). These principles are now considered to be the fundamental elements of Lean Manufacturing by the Lean fraternity.

Taiichi Ohno had been one of the developers of several of the Lean techniques. His book titled *Workplace Management* (1982), offers a firsthand account of the origin of these techniques. Ohno is often cited as the “inventor” of the supermarket and the original prosecutor of *muda* (waste) in operations. His work is therefore considered valuable for research.

Finally, Smalley, wrote a practical guide on the implementation of Pull production in a process, called *Creating Level Pull* (2004). This is a rare resource that deals with the practical as well as technical aspects of Pull Production in very simple terms. No other existent author has comparable insight into the process of establishing a working Pull system. This text is used extensively in this study based on its close match to the topic researched in this study.

1.5 DEMARCATION OF STUDY

This study is limited to the operational area of the particular Rosslyn-based exhaust manufacturer (ABC Manufacturing). The manufacturer is a South African subsidiary to a larger multinational company based in Europe. The manufacturer has proven itself as a leader in the exhaust manufacturing industry. The study is further limited to the despatch and production scheduling aspects of the operation, with special interest in the supermarket implementation.

Management of the organisation requested that the name of the organisation be withheld. The study is conducted over a period of a year. It looks back starting from the implementation in 2005 through to production practices in 2010.

This study could be best described as a case study. The researcher attempts to establish the suitability of the techniques used by the manufacturer in the particular environment for achieving the preset operational objectives. The research objectives underline this approach. In addition the researcher attempts to broaden the general understanding of the operational environment by addressing barriers that were overcome and lessons learnt.

1.6 SOURCES

Various sources of information were used to conduct the research. These include:

- literature on the topic of Lean manufacturing and literature reviews on the use and implementation of supermarket systems;
- interviews with managers of the manufacturer who were involved in the project will be conducted to understand the implications of the implementation of such systems; and
- interviews with technical and management staff at the plant will help to determine the levels of success of the project.

1.7 DEFINITION OF TERMS

The following terms are used consistently in this study to mean the following:

- Lean Manufacturing – "... also known as the Toyota Production System, means doing more with less – less time, less space, less human effort, less machinery, less materials – while giving customers what they want." (Dennis 2007: 13)
- Lean Manufacturing Principles: Carreira (2005: 2-3) identifies the principles of Lean Manufacturing as adding value to a product or service, achieving uninterrupted flow, adopting a system wide view of the value stream and continuously eliminating waste from the system.
- Pull System – "Pull means that nobody upstream should produce a good or service until the customer downstream asks for it" (Dennis, 2007: 71).
- Kanban – This is a Japanese word that could be translated to 'signboard' or 'card'. According to Gross & McInnis (2003: 1-4) it is a scheduling method that makes use of visual signals, typically a card, to dictate the type and amount of parts to be produced.
- Supermarkets – "... a supermarket is a central storage location where raw materials are stored near their point-of-use, so customers can pull them as needed. It works just like the supermarket where you buy your groceries – hence the name" (Gross & McInnis 2003: 185).

- Total Quality Management: “Total Quality Management is defined as both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organisation. It is the application of quantitative methods and human resources to improve all the processes within an organisation and exceed customer needs now and in the future” (Besterfield et al 2003: 1).

1.8 STRUCTURE OF THE PAPER

This study starts with an in-depth literature review to set out various views and approaches to the study field. This forms the theoretical benchmark against which the research findings are later tested.

Data were collected by means of interviews with various managers and staff members of the manufacturer, as well as on-site inspections. These findings are quantified and validated through cross-referencing.

The data based research findings are then compared to the literature review to test the applicability and the implementation success of the use of the Lean tools at the manufacturer’s plant. Conclusions are drawn and recommendations formulated based on these comparisons.

The structure of the paper is as follows:

Chapter 1: Introduction and Problem Statement

Chapter 2: The Literature Review: This chapter shows and highlights important and current thinking around the topic and problem statement.

Chapter 3: Research Design/Methodology: This chapter defines the research methodology that was applied in the study. It highlights the research problem and explains the various research parameters. It also includes the data collection methods used and indicate measures that were taken to ensure validation and reliability of findings.

Chapter 4: Presentation of Research Results: The situational background, interviews and discussion of the research findings are presented. The findings are interpreted, with important aspects highlighted.

Chapter 5: Comparison of Actual Design to Suggested Best Practices from the Literature: This chapter includes a comparison between the results of the literature review and the Rosslyn data to determine gaps in either the literature or the application. Successes and lessons learnt by means of the research are then offered and discussed in conclusion to this chapter.

Chapter 6: Conclusions and Recommendations: This chapter concludes the study and provides recommendations based on the findings and investigation. It revisits the research questions and offers concluding comments to these. It closes with remarks regarding the contribution of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews available literature on relevant topics. It starts by orientating the reader in terms of the context of the automotive industry in South Africa and deals with the fundamental business aspects, such as the size and attractiveness of the industry. The focus then shifts to a consideration of literature on the topic of Lean manufacturing, looking at the history of Lean, its principles and various scheduling techniques used in the practice of Lean manufacturing.

2.2 BUSINESS AND MANAGEMENT CONCERNS

During the last quarter of 2009, South Africa recorded a gross domestic product (GDP) of R624 billion or R2.4 trillion for the year 2009. Manufacturing accounted for 15.5% of the quarterly value and 15.1% of the annual GDP (StatsSA 2010). The manufacturing sector paid out R51.4 billion in employee compensation in the same quarter.

The automotive industry in South Africa invested R2.5 billion in 2009, this followed R3.3 billion of investments in 2008 (NAAMSA Quarterly Review 2010). Domestic vehicle sales were 533 387 in 2008, but dropped to 395 222

in 2009 and were expected to increase to 443 000 units in 2010. The global recession is put forward as the main contributor for the lower sales in 2009 and 2010. However, the fact remains that the industry is a major contributor to the South African economy.

The SA motor industry has created a large supporting industry of component manufacturers. There is an estimated 200 tier 1 component suppliers (firms supplying directly to Original Equipment Manufacturers (OEMs)) and another estimated 150 tier 2 suppliers (firms supplying to tier 1 suppliers and upward). Components only has been responsible for more than R44 billion worth of parts exported to European and African countries as well as the United States in 2008 (AEIC Automotive Trade Data 2009).

Of the components exported, catalytic converters have been the most exported part, accounting for almost half the mentioned exports and totalling R24.2 billion in 2008. Catalytic converters are components used in exhaust systems to remove harmful elements from exhaust gasses. Exhaust systems are also exported, but on a much smaller scale than the converters, yet formed the third largest exported item in 2008, with R1.9 billion worth of foreign currency. Thus, this is clearly an attractive industry.

This is significant to the business owner or manager seeking to understand how to enter an attractive industry such as this. The resources-based model

argues that each firm has access to a ”...unique set of resources and capabilities that provide a basis for its strategy and that is the primary sources of its returns” (Hitt, Ireland & Hosskinson 2005: 19). Hitt et al further argues that when these resources are combined in particular arrangements, it creates capabilities. Capabilities could also be defined as skills used by the organisation to operate, maintain and/or manage such resources. It is the combination of such resources and connected capabilities that creates a competitive advantage. Once this is applied to an attractive industry by means of an appropriate strategy, it could lead to superior returns.

Following this argument, the resources required by the exhaust system industry are known and relatively uncomplicated to acquire and operate. These resources have been in use for several decades and have been applied in numerous other industries. The capabilities are thus relatively uncomplicated. The argument then leads to the question of what strategy to apply to ensure continued success and returns.

In this study, the strategy, resource and capability mix that were applied by an exhaust system manufacturer in Rosslyn (North-West of Pretoria in Gauteng, South Africa) are described in an attempt to understand how these benefited the manufacturer in order to achieve above-average results.

2.3 A BRIEF HISTORY OF MANUFACTURING

Black & Hunter (2003: 2-8) describe the evolution of manufacturing by referring to major advancements in manufacturing technology as 'industrial revolutions'. They identify four main revolutions based on the technology, layout and economic principles that shaped each – Table 1 summarises these.

These revolutions started with home-based craft and cottage type operations where skilled craftsmen and artisans worked on custom designed components and products using basic tools. The first revolution was that of utilising powered equipment and mechanisation to change these workshops into factories with a range of more complex powered tools. This opened the way for large scale operations like steel production and weapons manufacture.

Henry Ford introduced his well-known moving assembly line in the early 20th century (Stevenson 2009: 23-24). This started the second era or revolution and many followed his example. The main driver of this technology was the high repeatability and resultant low cost manufacture otherwise known as mass production. The term economy of scale became widely used.

	1st Revolution	2nd Revolution	3rd Revolution	4th Revolution
Time Period	1840-1910	1910-1970	1960-2010	2000 to date
Manufacturing System design	Job Shop	Flow Shop	Linked cell TPS	Integrated Manufacturing Computerised
Layout	Functional layout	Product Layout	One-piece flow via linked cells	Linked assembly of large modules of subassembly
Enabling Technology	• Power for Machines • Steel Production • Railroad for Transportation	• Moving Final Assembly Line • Division of Labour • Standardisation leading to Interchangability. • Automatic Materials Handling	• U-Shaped cells, Kanban • Rapid Die Change • Zero Defect • Total Preventative Maintenance	• Virtual Reality • Simulation • 3D Design using low cost high-performance computers
Company Names	Whitney, Colt, Remington	Singer, Ford	Toyota Motor Co, GE, HP, Omark,Harley Davidson	Boeing, Lockheed, Dell, Mercedes Benz
Economics	Economy of Collected Technology	Economy of Scale, High Volume, Low unit Cost	Economy of Scope, Wide variety of low cost	Economy of Modules, Smaller Factories

Table 1 – The History of Manufacturing

Source: Black & Hunter (2003: 2)

Taichi Ohno, former Vice President of Manufacturing for Toyota Motor Corporation (TMC), became instrumental in the development of the Toyota Production System (TPS), after joining the company in 1945. Some of the values on which TPS was based are: mutual respect, relentless waste reduction, questioning the status quo and reliance on facts rather than reports. These led him to ultimately discard many aspects of the mass production model (Ohno 1982: 38-40) in favour of more progressive models like that of Just-In-Time (JIT).

The new methods, however, initially created more problems than solutions, which led Ohno and his team to look for ways around these problems. For instance, large amounts of inventory were unacceptable at TMC, due to the cost and space requirements, but inventory allowed for dealing with unavoidable variations. The only solution was to replace such variation with stability (Dennis 2007:29-30).

In order to achieve stability in production, Ohno (1982: 76-79) developed a low inventory strategy that was based on elimination of different types of variations and eventually evolved into Kanban and JIT. This gave rise to various new concepts like Rapid Die Change, U-shaped cells, Zero Defects and Kanban.

These developments allowed TMC to compete with American and German corporations on cost, quality and variety even though their operations were

much smaller than those of the competition. TPS had become a competitive advantage in the automotive industry.

TPS was first documented by Womack, Jones and Rice in 1990, and eventually became known as Lean Production. This was quickly adopted by some Western companies like Harley Davidson and General Electric.

Black and Hunter's 4th and last revolution is that of Computer Integrated Manufacturing. The development of low cost but high performance computers have made possible the ability to design, manufacture, assemble and deliver a product with minimal human labour. This includes combining the efforts of geographically dispersed team members, design, simulated manufacture and assembly of products prior to the first components being ordered and the design and assembly of the manufacturing process and equipment even before the actual factory has been built. This allows for perfect product and production design and quality as well as reduced factory sizes to limit the cost of production overheads.

2.4 THE LEAN MANUFACTURING REVOLUTION

Lean manufacturing is vastly different to traditional manufacturing practices and these differences are rooted in the principles and philosophies of Lean thinking.

2.4.1 Fundamental Principles of Lean Manufacturing

Womack & Jones (1996: 15-26) defines Lean Manufacturing by the principles it underpins. These principles can be listed as the following:

- Specify the value and identify the value stream
- Flow
- Pull
- Perfection

2.4.1.1 Value to the Customer

Womack & Jones (1996: 37-49) describe the concept of **value** as those elements that, for a specific product or service, add value to the customer at that time and place. The customer ultimately has to pay for all the travels and processing of the product he buys. In an era of globalisation, this is no longer acceptable and customers are no longer uninformed. The result is increased pressure on organisations to reduce waste and the resulting cost to the customer. In doing this the organisation has to analyse the entire value stream of the product – from the point of the raw material being mined to the point where the customer consumes it.

For instance; a process might consist of a few simple tasks performed by separate people. The process, however, is such that an item would wait at each individual stage for processing due to the person being occupied by other tasks. The result is then that the total time the item spends in the system could be days or weeks, while the actual value-adding time (when the persons process the item) is only a few minutes or a few hours. In this example the customer is not even aware of the costs and delays locked up in these inefficiencies, yet he ends up paying for it in money and time.

2.4.1.2 Flow and Pull

Womack and Jones's (1996: 50-89) second and third principles mesh very delicately and without obvious causality form the intricate requirements of one-another. Just as in the case a mountain stream, **flow** is a natural tendency, but it is hindered by many aspects of the environment. The reason for wanting flow is obvious to the production manager as it signifies a stable production rate. If he has a predictable stream of products coming off the line, he can plan ahead. The environment of a factory, however, does not (always) allow this. This 'environment' is the result of breakdowns, work-in-process inventory, mistakes, quality problems and many more.

Edward Deming identified 14 principles on which quality improvement and assurance should be based (Besterfield et al 2003: 4-6). He presented these to 21 presidents of industry in Japan in 1950. These principles became the basis for solving quality problems in the TPS.

The development of Total Productive Maintenance in 1970 by Nakajima (Santos et al. 2006: 108-110) enabled Toyota production managers to solve breakdown and equipment problems. These tools and others like Kaizen, SMED and Poka-Yoke allowed production engineers and managers to eliminate the hindrances in the production process to ultimately achieve smooth flow of production.

While these techniques were successful in creating flow, by far the most common and most effective means is through Pull production. Just as the

water in the mountain-stream-analogy gravitates down the side of the mountain, **Pull** production refers to a production planning concept that is disciplined to only respond to demand of the product. This requires the system to have the capability and the capacity to respond instantly.

Capability refers to the ability to produce the required quality or specification, while capacity refers to the cycle time and availability of the process. If these prerequisites are not in place, a Push system will result.

In contrast to Pull, a Push system produces parts in large quantities due to long setup times, long cycle times, large delays or transportation requirements in between operations and equipment design limitations. A batch of parts is processed one operation at a time. This batch is then 'pushed' through the series of operations by means of regular production planning exercises. Push production forms the basis of typical mass production operations, and thus the fundamental move away from mass production by Ohno (1982: 37).

Many production planning systems also incorporate some scheduling algorithms that calculate the most appropriate next step to ensure the business goals are achieved. Numerous techniques have been developed and improved over the years. Such techniques are typically fairly effective within a narrow range of conditions and as such have limited application or effectiveness. Davis and Heineke (2005: 609-619) offer an overview of several techniques while Vollman, Berry and Whybark (1997) delve into the

effectiveness and problems associated with some of these techniques. Typically such techniques need highly qualified personnel or complex software to apply them commercially.

A Pull system makes use of a scheduling technique called Kanban. The logic of Kanban is much simpler and to a large extent self-regulating. Kanban is the Japanese word for “visible record” (Schonberger 1982: 219-239). According to Schonberger, the importance of the Kanban is that it becomes a messaging system that calls for a single part or a pre-determined (small) quantity of parts from the previous workstation. Once the unit has been completed and supplied, the upstream station would in turn call on its supplying station to replenish only what it has used. The process is repeated at each station, delivering small quantities of parts as and only when they are called for and only in the exact (small) quantity prescribed by the system designers.

Several types of Kanban systems have been devised for differing purposes, but the principles remain the same as above. The benefit is that resources are not required to produce more than can be sold. Any idle labour time that results, should be used to perform cleaning, maintenance and improvement tasks. This releases the operator from a monotonous machine-minding job to become a productive and involved team-member.

It is then clear that Flow and Pull is interrelated and although not completely interdependent, they are mutually supportive.

2.4.1.3 Perfection or Continuous Improvement

Womack and Jones (1996: 90-98) refer to organisational learning as "Perfection" and they combine into this process the techniques of *Kaizen* and *Kaikaku*.

Kaizen is the term used for **continuous small improvements** and is often practiced as kaizen events or kaizen 'blitzes'. During these a particular section stops production and over three days the staff from the section is trained in various Lean techniques, collect data on their section, solve problems and finally implement the new ideas into the area. In most cases the Kaizen event would be repeated some time later to solve and implement even more ideas and problems. Womack and Jones (1996: 91) show figures of improvement of almost ten-fold increase in productivity, 50% reduction in space utilisation and 92% reduction in accidents and compensation costs. These were achieved through 7 events over a 3 year period.

Kaikaku, as an alternative, is when large-scale changes to the entire supply chain is made to eliminate the waste and quality problems that exist due to archetypical manufacturing decisions. Womack and Jones (1996: 92-93) quote an example from the glass manufacturing industry where the glass goes through three processes: float, press and encapsulation. Typically this will be stretched over three different plants, possibly located far apart and designed for individual batch and size optimisation. A Kaikaku would then see the three plants being integrated into a single plant and located next to the

automotive assembly line. Design of the new facility would then be optimised to the rate of demand by the assembly line.

Many such examples have been quoted where Kaizen and Kaikaku (Womack & Jones 1996: 102-150) had been implemented and the improvement figures astound every time. The combination of Kaizen and Kaikaku is intended to yield a continuous stream of large and small improvements to its operations. This is intended to ultimately propel the organisation into a position of leadership or perfection in terms of productivity and quality.

2.4.2 Lean Philosophy

Liker (2004:13) suggests the 4P model to explain the Toyota philosophy:

- Process
- Problem Solving
- Philosophy (Long-Term Outlook)
- People and Partners

Into this model he builds 14 principles on which the success of Toyota was based. However, central to Toyota's success was a culture of unity and support to the cause or strategy of the organisation. The strategy in turn was based on achieving both short and long term objectives simultaneously.

Aspects of Liker's model coincide with that of Womack & Jones's, for instance; with relation to process principles and problem solving related principles.

2.4.2.1 Process

These include aspects like creating Flow, using Pull systems and standardisation of work. Liker (2004: 129-139) goes into more detail and adds the following:

- a culture of stopping to fix problems;
- the use of visual control to highlight problems; and
- the use of reliable technology to prevent problems with flow and quality.

The first of these warrants discussion:

At the heart of the ‘stop to fix problems’ culture lies the concept of Jidoka or Quality At The Source (QATS). Nash and Poling (2007: 24-25) point out that quality at the source is a very effective tool in improving the quality of product. It is also a very simple process and almost intuitive. The rules of QATS are that prior to adding value to a part it is to be inspected for critical and obvious defects. Any defective parts are to be removed from the line at this point and this must be reported. Removing the part ensures that no further value is added to the defective part downstream. Reporting the defect aids in continuous improvement. The root cause of the defect needs to be understood and addressed. It also aids in potentially identifying a shifting process mean. This could be the start of a series of defects or a randomly recurring defect upstream.

Although the process principles as laid down by Toyota are more stringent than described above, the concepts are accurate. According to both Liker (2006:307-313) and Schonberger (1982: 47-83) the unfailing focus to elimination of quality problems are critical to improvement of the process as a whole. Schonberger (1982: 69-74) goes on to describe the several methods Toyota used to expose problems to further enhance the robustness of their production processes.

2.4.2.2 Problem Solving

The philosophy of problem solving as described by Liker (2004: 223-263) is closely linked to that of organisational learning, as described by Senge (1990: 17-26).

Liker (2004:221) lists three principles to describe this philosophy. The first is *genchi genbutsu* – the belief that "You cannot be sure you really understand any part of any business problem unless you go and see for yourself firsthand." (Liker 2004: 223). He indicates that this attitude is not intended to defy the credibility of sub-ordinates who report on matters; rather that it serves as recognition of the importance of the message.

The second principle is to make decisions slowly and by consensus, thoroughly considering all options and then rapidly implement them. This principle governs the amount of planning that goes into any projects, regardless of how routine it might be – until all the data is on the table and in an efficient communicable fashion, the planning is not complete. This

principle ensures the full commitment of all parties involved and gives the opportunity for all the counter-arguments to be heard and considered.

The last principle addresses continuous improvement but coincides with a reflection about the situation and the mistakes that were made. The individual is held accountable for making a mistake, with the purpose of learning why the mistake was made *and* learning how to avoid this mistake in future.

Schonberger (1982: 28-33) describes an additional form of continuous improvement. This could be described as an intentional drive towards improvement. He uses the example of how Just-In-Time production was developed through intentional starvation of production lines. A traditional production line would follow a batching strategy. The reasons for this are typically the length of setup times and the cost of potential stock-outs.

Management would set production quotas for shop-floor staff and failure to meet this is often ‘rewarded’ with enforced overtime and reprimands for the entire team. The result is that any problem on the floor is met with complete involvement of all team members. As soon as the quotas are suitably met, the batch quantities are further reduced. The quotas are maintained, resulting in problems cropping up due to, for example, the long setup times or quality problems. This process is repeated until no more problems are identified and smooth production flow is achieved.

Teams are assisted by experts and engineers to solve these problems and end up finding creative ways of overcoming these. Other effects of this are that downstream stations can now identify errors sooner and more regularly and return these to their origin, but with the intention of solving the cause of the defect. Peter Senge (1990: 151-159), calls this process one of creative tension, this is where the person's creativity is unleashed due to the tension experienced.

2.4.2.3 Long-Term Thinking

Liker (2004:69-84) suggests that Toyota has been following a long-term philosophy in terms of strategic planning. This philosophical approach has served to create a unified and disciplined approach towards decision making, growth and any other strategic matter. This set of values lead Toyota to view itself as having a purpose that is beyond that of making money, but rather that of being responsible and generating value for all stakeholders.

This approach has often seen Toyota's management make decisions contrary to short-term financial goals. Some examples include the dealerships being refunded by Toyota for losses due to government imposed tax changes, yet Toyota were not refunded for these by the US government (Liker 2004: 73-74). This was done to build loyalty and customer satisfaction in the long-term.

In the 1980's General Motors (GM) and Toyota engaged in a joint venture in which Toyota took over the management of a GM plant in Fremont, California staffed by American personnel. This facility was named the NUMMI plant.

During 1987 and 1988 orders were dropping for the Nova (a vehicle manufactured at NUMMI), yet in order to maintain the respect and trust of employees, no-one was laid off. Instead, staff members were reassigned to Kaizen teams and other tasks until production demand picked up again (Liker 2004: 74-75).

Similar thinking could be found in Organisational Behaviour studies. An appropriate model is that of Gross and Shichman (1987: 52-56) that identifies the need for a sense of history, oneness, membership and increased exchange to develop a cohesive culture. In the NUMMI example the event became part of their history, a story to tell new recruits and it confirmed the 'oneness' of and 'membership' to the larger team.

These examples serve to emphasise the commitment to people, customers and partners that were entrenched in the Toyota culture. The principle was simple: ensure a solid foundation of the values of trust and respect to ensure long-term growth and mutual benefit and lasting customer satisfaction.

2.4.2.4 People & Partners

Three principles form the basis for Toyota's respect for people and partners. Firstly, Liker (2004: 173-174), explains how leaders in Toyota are groomed and grown into their positions. On one hand this requires a long-term view of business that dictates the need for early identification of potential leaders and then groomers to take on the challenge of mentoring the younger mind. It also

means avoiding the temptation of buying a leader from outside to instate a ‘quick-fix’ as is so often seen in corporate business.

The second principle deals with the approach to people and organisation structures. The important issue here is to create a culture and to copy that culture to new employees as soon as possible. Structure and culture goes and-in-hand at Toyota. Their design is based on strong emphasis on team structures, but also on individual performance. This is an important deviation from the individualistic approach to business often found in mass production environments where the ‘division of labour’ dogma is applied blindly.

Finally, Toyota view suppliers as partners rather than adversaries. Toyota chooses its suppliers carefully, first by giving small orders to test the commitment and sincerity. Once the supplier has proven itself, it gets drawn in and is almost hand-raised to the Toyota standards. It will not be kicked out, except for the worst of behaviour. No bullying tactics are allowed under the Toyota Production System, rather, Toyota will make available resources to teach and challenge suppliers until they are able to perform to the Toyota standards.

This method of partnering with suppliers has been used successfully in numerous other situations. One such case is described by Williams (2006: 3841-3844) of an office furniture retailer introducing its supplier to Kanban. The benefits being stabilising the order schedules, improved communications and general improved problem solving.

2.5 LEAN SCHEDULING AND TOOLS

Mahoney (1997: 3-6) describes the evolution of production scheduling along the argument that this is a potential competitive advantage and shows how Japanese manufacturers, including Toyota, have been evolving to this point over the period from the 1960's to the 1990's. He argues that initially labour cost was a competitive advantage for Japan, but this came at the cost of quality. After introducing Deming's teachings, they found quality to be the new driver, soon to be replaced by volume of production as customers started demanding their high quality products. The next step would be to add variety to volume and they found the two did not mix well.

Toyota management soon found that customers wanted a high-quality, low cost product or service, but with no waiting time. Since they knew how to produce high quality at low cost, the next challenge was not infinite variety, but rather how to manage time. More specifically, how to produce the right parts at the right time.

At that time (1960's), technology only allowed this by increasing inventory, increasing capacity or by improving forecast abilities. None of these were acceptable solutions, instead Toyota introduced Just-In-Time and with that came Kanban, and Quick change-overs.

Dennis (2007: 69) states that during the same time that Toyota was finalising their Just-In-Time scheduling strategies, the West had managed to

computerise MRP (Material Requirement Planning) systems and introduced Capacity planning modules and eventually designed ERP (Enterprise Resource Planning) software.

Kanban and quick change-overs, however, opened the way for Toyota to produce small quantities of a large variety of products in a limited period – such as a day or a shift. The significance of this was extensive. On the one hand it eliminated the need for massive capital investment in capacity increasing projects. On the other hand, it improved responsiveness (and customer satisfaction) by orders of magnitude. It further obviated the need for outsourcing, which tends to be habit forming.

A final benefit is the direct equipment availability improvements that result from earlier mentioned quick change-overs. The benefits were that of problem solving and equipment upkeep and maintenance leading to higher equipment availability as well as that of accounting and amortising interest.

2.5.1 Kanban & Supermarkets

As mentioned above, Kanban is a technique used to schedule production in a Pull production environment. Smalley (2004) describes the implementation of a Kanban process as follows:

1. Recognising the need for “Level Pull”
2. Matching current capability with demand.
    a. Types of Pull systems
    b. Inventory management

3. Appointing a “Pacemaker”
4. Upstream flow control – synchronising a batch process to a Kanban process
    a. Create Supermarkets
    b. Size Supermarkets
    c. Batch process control
5. Sustaining “Level Pull”

2.5.1.1 Recognising the need for “Level Pull”

Dennis (2007:83) summarises the need for level production in three simple benefits:

- Shorter Lead Time
- Less Inventory and WIP (Work-In-Process)
- Less strain on the workforce

Smalley (2004: 5-8) identifies some of the problems experienced in a typical Push system. He points out that although the production planning of these systems are following orders from customers or are tuned to typical demand patterns, the end result is more often wrong than it is correct. He offers the following reasoning: since a Push system work on a batch build principle, there are significant time lapses from a production order being released until it is ready for delivery. This lead time could be several weeks during which time the customer requirements have changed.

This often results in the wrong items being available to deliver to the customer. Production planning will try to satisfy the immediate needs of the customer by starting at the finished goods warehouse, find limited numbers of the required part only to move one process upstream at a time to identify work in process that could potentially be re-allocated to the new requirement. This would then mean rescheduling the production to suit the new order. This process of re-allocating work-in-process creates new gaps and more confusion.

Even more concerning is the fact that a relatively minor order change by the customer will be amplified at every upstream process step. The variation gets progressively worse as the delivery change has upstream effects.

2.5.1.2 Matching the current capacity with demand

One of the important lessons that Smalley (2004: 10) and various others allude to (and sometimes actually state outright) is the process of taking small initial steps toward large-scale improvements. According to Liker (2004: 237-239) the western practice of quick decisions and big turnarounds sometimes leads to spectacular confusion and devastation. In contrast, a process of small and simple initial changes allow for easy learning, building of confidence and, if need be, ease of reversal to re-strategise should the suggestion be less effective.

Following this thinking, Smalley (2004: 7-8) offers the option of introducing a temporary finished goods buffer to separate the erratic demands from the

customer from the production facilities. This is nothing new in production circles, but in this case it serves a purpose greater than simply storing large quantities of finished goods.

This buffer will allow the plant a measure of stability while a Pull system is installed; much like the breakwater protects ships inside a harbour from the onslaught of the tide and waves. This small measure of stability gives the production floor the opportunity to start implementing Kanban.

- *Different Pull Systems*

The shopfloor is a dynamic environment that ultimately reacts to the demand of the customer. Any reactive system is highly vulnerable in being unable to react quickly enough. Traditional Push systems tried to overcome this problem by forecasting demand and then attempted to be pro-active and *produce what the customer was expected to order. The failure of such* systems is described by Mahoney (1997: 17):

> *"Forecasts are necessary to allow reduced aggregate customer and supplier lead times by building ahead. If significant resources are expended to produce as forecasted, and the actual demand is less than forecasted, a direct loss in productivity occurs. The worst-case scenario is the situation where the lot size equals the forecast quantity. At the other extreme, if the actual demand exceeds the forecast, and the forecast lot has already been produced, the adverse consequence of an additional long setup will decrease available capacity when the difference is made up and severely impact the delivery dates of other products yet to be produced. Frequent expediting is indicative of this problem."*

A Pull system is a reactive system and also tries to satisfy the demands of the customer. The difference is in the application, however. For a reactive system to be effective, it needs to be agile and flexible. The human nervous system is a good example; a hand placed on a hot stove is removed quickly only as a result of fast communication between senses, nerves and muscles. It is not slowed down by complicated procedures and processes.

A Pull system, therefore, should deliver exactly what is requested and only that which is requested. This needs to be done quickly and efficiently without the encumbrance of complex procedures. This can be achieved by three basic methods:

a. Replenishment Pull
b. Sequential Pull
c. Mixed Pull

Replenishment Pull holds final parts in storage for the customer to withdraw. A withdrawal will trigger replenishment of the parts by the previous (last) process – in most cases; assembly. This, in turn, will trigger upstream processes to produce or to order the corresponding parts or components. Dennis (2007:71-76) suggests that this works well in the frequent order and short lead time environment of the automotive industry.

Sequential Pull is the most difficult option as it requires short and stable lead times as well as high availability of equipment. It allows the customer's order

to be passed to the start of the production process and then produced to order (Smalley 2004: 16-18). Typical and suitable applications of this are found in fast food restaurants where the holding of finished goods is unacceptable, but the process leadtime can be engineered to be suitably short.

Mixed Pull identifies some items to be sent to the start of the process as described in the Sequential Pull procedure. Other items are taken from stock and replenished as per the withdrawal trigger that results from the customer collection or shipment. The choice between which items are treated as sequential and replenished is again dependant on the rules for Sequential Pull. Under fair consistency in lead time and equipment availability, runners[1] and repeaters[2] could be pulled *sequentially*, while strangers[3] are made-to-stock.

However where lead time is highly variable, it pays to make strangers to order while runners and repeaters are made to stock. This allows for a stable production plan in high and medium frequency parts and low frequency items are 'fitted into' the plan when possible.

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[1] Runners are parts that form the majority of total volume.

[2] Repeaters are regular or frequently run parts, but constitute a significantly smaller portion of total volume.

[3] Strangers are those parts that are run infrequently or even seldom.

- *Inventory management*

Inventory managers are familiar with terms like safety stock, buffer stock, economic order quantities, lead time to replenish and order cost. These terms are well documented by numerous sources such as Vollman, Berry & Whybark (1997:13-52), but need to be re-considered in a Pull environment. Typical stock control systems are automated to such an extent that the people working there are typically a greater danger to the system than anything else. Human error is normally to blame for lost stock, incorrect locations and quantities and numerous other day-to-day problems. This is normally addressed with training, while the source of (at least some of) such problems are often overlooked.

Smalley (2004: 23) blames some of these errors on the lack of visual controls to allow staff to make informed decisions. He suggests that the following implementations should be made in finished goods storage:

a. introduce dedicated locations per part number;
b. design locations to promote First-In-First-Out (FIFO) inventory control;
c. signage should be added to locations indicating maximum quantities to be stored in the location – this should prevent overfilling and would represent the start of the pulling cycle;
d. by using dedicated locations, parts can be stored according to demand or frequency of use – thereby limiting the staff movement in the store when searching for parts; and
e. finally a simple inventory control system can now be put in use to track use and movement trends of each part number and react accordingly.

Authority levels should be implemented to flag drastic changes in demand and critical production related problems.

The use of visual management in storage and other areas is supported by others, such as Dennis (2007:67-93) and Louis (2006: 118).

2.5.1.3 Appointing a "Pacemaker"

Smalley (2004: 27-30) suggests that a pacemaker be introduced into the system. The purpose of this station is to control the overall flow of production. This would act as a scheduling station for the entire plant. The need for this is found in the confusion that often exists on a production floor as production plans are changed and updated so often that few departments can keep track of it and eventually start following their own schedule partly out of frustration and partly out of a production need.

Goldratt and Cox (1992: 93-118) also refers to of a pacemaker of sorts. They are well known for the Theory of Constraints (TOC) and the Drum-Buffer-Rope (DBR) theory. The DBR theory states that the constrained resource should be the drum or the one setting the pace at which production should progress. This drum is then linked to all stations via the rope – a symbolic connection indicating the submission of all resources to the pace of the drum. Finally, the drum is protected by a buffer of materials to ensure the constrained resource does not stop even though the rest of the line might do so.

The important difference between Goldratt and Smalley's theories is that Goldratt emphasises that the drum must be the constrained resource (Goldratt and Cox 1992: 210-216), while Smalley offers another possibility. In Smalley's scenario, there are no constrained resources or the constrained resource is 'moving' around the plant due to scheduling changes and product mix changes. This makes it increasingly difficult to track and pin down the drum. According to Smalley (2004: 30) the customer dictates the demand and the production rate. As such the pacemaker can be identified, by the design of the Pull system. A simple rule is offered:

a. if a Replenishment Pull system is in place (holding finished goods of every type), the final station will be the pacemaker;
b. if a Sequential Pull system is in place (holding no stock and produce on demand), the first station will be the pacemakers. (this type of pull system is often hard to maintain and therefore used quite seldom); and
c. where a Mixed Pull system is used the pacemaker is dependent on the type of product. Typically a supermarket will then be installed in a strategic position to alleviate the complexities of running under differing rules and thus maintain the pacemaker in a single workstation.

The pacemaker has the important task of pulsing work through the plant, as Goldratt and Cox (1992: 210-216) indicated when they coined the term "Drum". Equally important is to ensure the pacemaker is capable of maintaining the beat. This requires the production to either be scheduled below capacity or to be levelled in some way.

Liker (2004:113-127) points out that *Mura* or 'unevenness' is the cause of *Muda* or 'non-value adding'. This has brought about the concept of levelling which in turn has become a fundamental principle (that of flow) in the Toyota Production System and is embodied in the Heijunka method. *Heijunka* or 'levelling the workload' requires one to ensure that the production plan for one day looks exactly or at least almost exactly the same as the next day. This levelling is often achieved by introducing a timed production schedule and activated by a 'milkrun' to coincide with the interval period.

A milkrun is described by Domingo, Alvarez, Peňa and Calvo (2007: 142) and has the basic purpose of supplying the pacemaker with the correct parts or materials as well as a Kanban order for the next interval period. The material handler responsible for the milkrun will collect full containers found on the predetermined path and swaps these for empty containers and the respective Kanban cards.

The timed delivery of parts and Kanbans allow for precise production planning and lead to ease in releasing of materials and production orders to the shop floor. This results in a production rhythm that is similar from one day to the next. In practice this means giving up the long held beliefs about batch production and requires production teams and engineers to address change-over problems and demands. Ultimately smaller batches are possible and planning is eventually done on the basis of container size (typically small enough to be moved by a single person on a trolley).

2.5.1.4 Upstream flow control

It often happens in real systems that, due to various constraints, it is too expensive or physically impossible to extend a Kanban system infinitely. Reasons include huge capital investment in batch production equipment or distance constraints – where parts are imported and shipping schedules, regulations or costs do not allow for small or regular shipments.

In these cases it becomes necessary to install a so-called supermarket or market in short. Gross & McInnis (2003: 185-188) also suggest that a supermarket can be used as a stepping stone towards introducing Pull systems. The concept was identified by Ohno (1982: 72-74) in US retail shops in the early days of Toyota.

The principle is very simple: relatively small quantities of a wide range of parts are presented to the customer and then replenished on a daily basis. In the retail shop, this allows the shop owner to serve a wide range of customers and achieve low purchase prices through bulk buying.

In manufacturing terms this translates into batch production on the supply side and Kanban call-off on the demand side. A press-shop is typically run as a batch operation due to the setup constraints. As long as batches of all types of all parts are presented continuously, there is no need for the press-shop to not produce in batches. These batches are then presented to the assembly line in a supermarket fashion, allowing the downstream assemblers to take the parts they need from the market, assemble the product and start with the

next product. There is no longer a need to assemble in batches, since all parts are available at all times.

In terms of dealing with overproduction and oversupply wastes production planning simply need to monitor demand and schedule press-shop batches accordingly. Assembly then follows as a logical outflow, with limited interference by production planning other than the next Kanban.

The implementation process thus follows the simple logic of:

a. Create Supermarkets
b. Size the Supermarket
c. Upstream Batch Process Control

Few sources discuss the establishment of supermarkets, but Gross & McInnis (2003: 185-188) agree with the following principles:

- Dedicated storage – this will avoid confusion and resulting wasted time and motion.
- Ease of access – aisle width, height, location design and container presentation/design all add to the effectiveness of the market.
- Control system – the Kanban card is the authorisation to withdraw materials and as a result needs to be provided for.
- Location is usually a matter of what is feasible, while visual control is often an important consideration.

Sizing of the supermarket depends on a range of variables, the most important of which are the following according to Bicheno & Holweg (2009: 143-161)

- The buffer stock, safety stock and batch quantity
- The amount to hold in the market is often determined by the following formula:

  Market Inventory = Average daily demand + Anticipated variation in Demand[4] + Safety Stock
- The frequency with which the downstream stations are replenished.

Smalley (2004: 60- 68) adds the following criteria:

- The load or pack size
- The delivery strategy to the downstream stations.
- As an alternative to the above formula various trails could be run to determine a suitable stock quantity.

In order to control batch production of parts pushed into the market, *a trigger point* or *signal Kanban* is used. Typical production processes are governed by traditional performance measures that focus on machine utilisation rather than material flow. The effect of this is usually large batches and overproduction leading to over-flowing storage facilities.

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[4] Anticipated Variation in Demand and Safety Stock is typically indicated as a percentage of the Average Daily Demand.

According to Pieterse et al (2010: 57-74) the signal Kanban sets a trigger point in the market. This trigger is reached as the result of a series of small withdrawals by downstream stations. Once this trigger is reached a production order is released. The production department is then obliged to produce only the stated batch quantity and only to proceed to the next order if and when it arrives.

The immediate reaction is that it is possible for an expensive piece of equipment to actually remain idle for a period of time or that the same piece of equipment might be forced to set up much more often than previously thought to be ideal. Either of these situations will lead to poor utilisation results and possibly loss of capacity.

In order to deal with this loss of capacity Smalley (2004: 64-65) suggests that a realistic number of change-overs should be determined by regarding the total available time and subtracting the production time to meet the average daily demand, the result of which should be divided by the duration of the typical setup. This gives an indication of the number of batches that could realistically be produced per day. Failure to meet these requirements indicates an immediate need for setup time reduction.

Lot sizes are determined by either allocating a fixed portion of the available time to each run before setting up for the next part or by specifying a fixed quantity of parts to produce for a specific part number. The first method

allows an easily repeatable daily sequence. The second option might run into the next day and loses the simplicity rather quickly.

Once the above has been determined, a lot size or 'lot duration' can be determined. Based on this the reorder or trigger point can be determined and appointed to the particular supermarket location / part number.

2.5.1.5 Sustaining "Level Pull"

Smalley (2004: 93-97) says that sustainability can only be achieved if the following aspects are maintained:

- continuous monitoring of customer demand;
- continuous performance assessment; and
- daily supervision of production control and assurance that work procedures are followed.

Customer demand fluctuates and changes over time and this will affect the stability of the Kanban system and the supermarket stock levels and triggers. Consequently demand needs to be monitored in order to make adjustments to the levelling parameters.

Performance measurement is critical in any system to ensure that problem areas are identified timely. Once identified these can be addressed and resolved. Performance measurement also has the effect of focussing the attention of all team members on the crucial aspects of the process, thereby ensuring a stable process. Supervision is important to oversee and ensure

that appropriate adjustments are made to the system maintain it. This also includes identifying drifting form standards and procedures, implementing improvements and visual or process aids.

2.6 SUMMARY AND CONCLUSION

This literature study shows that manufacturing had evolved over the last two centuries from being home and craft based, to the industrial period of large scale and heavy industry, this was followed by mass production, Lean Manufacturing and Computer Integrated Manufacturing. Lean Manufacturing started out as the Toyota Production System as initiated and developed by Taiichi Ohno, former Vice President of Manufacturing for Toyota.

It has been found that Lean manufacturing is based on several principles to achieve the manufacturing goals. These Principles include that of Value to the Customer, Flow and Pull and Perfection or Continuous improvement and are easily linked to the philosophies of problem solving, process thinking, people focus and long-term vision.

Lean Manufacturing addresses a number of operational aspects of which scheduling is one. Literature shows Lean Manufacturing adopted a fundamentally different approach to scheduling than had been used in industry at the time. Several techniques were born from this and are known as Kanban, Supermarkets, Level Production and Quick Change-Overs. These are often collectively referred to as Just-in-Time (JIT). These techniques were rooted in the above principles and philosophies.

The benefits obtained from the implementation of these and other tools have been far reaching. Toyota started out as a small, almost insignificant player in the automotive industry (Womack, Jones & Rice 1991: 48-58). However, through the introduction of Lean Manufacturing they have been able to grow into one of the largest and most profitable in the industry (Liker 2004: 3-5). The business benefits had included growth, increased competitiveness, and profitability.

CHAPTER 3

RESEARCH DESIGN / METHODOLOGY

3.1 RESEARCH PROBLEM

For a proper discussion of the research design, the research problem will be restated here as follows:

ARE THERE BENEFITS IN THE APPLICATION OF SELECTED LEAN TECHNIQUES TO ACHIEVE THE DESIRED SCHEDULING RESULTS AT A ROSSLYN BASED EXHAUST MANUFACTURER?

The following sub problems were formulated:

1. What does literature reveal about the philosophy and practices of Lean manufacturing?
2. What does literature reveal about the use of supermarket scheduling systems?
3. How was the project initiated and implemented at the Rosslyn factory?
4. Was the project successful in terms of meeting the operational requirements?
5. What barriers and obstacles were encountered and had to be overcome?
6. What lessons were learnt as a result of implementing this approach?
7. What recommendations can be proposed?

3.2 RESEARCH PARADIGMS

Various methodologies have been devised and applied for conducting research. Main categories include quantitative and qualitative research. These can be further distinguished into categories like historical, descriptive and experimental research designs. The purpose of this chapter is to identify and defend the particular methodologies applied in this study.

Three suitable methodologies were applied to this study and will be described and evaluated. These are Empirical Research, the Ex Post Facto Design and the Case Study Design.

3.2.1 Empirical Research

At an overview level this study could be described as empirical research. This research methodology is generally defined as data based, where the researcher needs to collect numeric and non-numeric data to support or reject a particular hypothesis. It has been described as follows.

> ***"Empirical research*** *is research that derives its data by means of direct observation or experiment, such research is used to answer a question or test a hypothesis; .... The results are based upon actual evidence as opposed to theory or conjecture; as such they can be replicated in follow-up studies. If empirical data reach significance under the appropriate statistical formula, the research hypothesis is supported. If not, the null hypothesis is supported (or, more correctly, not rejected) meaning no effect of the independent variable(s) was observed on the dependent variable(s)."*

[http://en.wikipedia.org/wiki/Empirical_research]

The outcome of such research will not offer proof, but will merely lead to probabilities. The Ex Post Facto and Case Study designs both fall under the generic methodology of empirical research.

3.2.2 Ex Post Facto Research

Leedy & Ormrod (2010: 229) writes on the Ex Post Facto method of research: “An experimental treatment (Tx) is introduced, and then a measurement (Obs) – a posttest of some sort – is administered to determine the effects of the treatment”.

The diagram shows the intended research approach.

Group 1	Treatment	Observation
	Time →	

Figure 1 – Ex Post Facto Research

Source: Leedy & Ormrod (2010)

This research method is relatively simple in that it observes the subject after a particular treatment has been administered. The researcher then reports on the apparent results of the treatment. In this case the subject is an exhaust manufacturer. The treatment in this case would be the design of the facility and resources the manufacturer uses to produce the exhaust systems. The observations are limited to the physical design and equipping of the plant as well as the processes employed to utilise these resources. It does not focus

on the soft issues of team work/problem solving training and culture related aspects of the operation.

Other types of research involve the comparison of a pre- and a post-situation in order to determine the effectiveness of a particular treatment. In this case, however, the manufacturer had been established as a 'green fields development' and as such there is no 'pre'-situation to compare it to.

3.2.3 The Case Study Methodology

The case study methodology is based on "…studies that are qualitative in nature and that aim to provide an in-depth description of a small number of cases" (Mouton 2005:149). According to Mouton, this method of research is applicable for business studies of companies and conducted by means of observations, semi-structured interviewing as well as documentary sources.

Leedy & Ormrod (2010: 137-138) suggest that a case study is the study of a particular person, event or program over a period of time. They argue that it is useful in learning more about a poorly understood situation, but that due to the limited view does not allow one to draw generic conclusions on the findings.

3.3 SELECTED METHODOLOGY

3.3.1 Research Procedure

The research procedure that will be followed for this paper is broadly based on a case study. The argument for this is based on the explanations offered by both Mouton (2005: 149-150) and Leedy & Ormrod (2010). The procedure to be followed is closely matched to that of Leedy & Ormrod (2010: 138) and is outlined below.

3.3.2 Chapter Outline

Chapter 2 documents what literature has revealed regarding the benefits of applying Lean principles in terms of designing and scheduling a plant. The rationale for selecting the particular case is pointed out in the opening paragraphs of Chapter 4.

Chapter 4 also compiles all the findings and interviews collected by the researcher. It discusses and formulates an understanding of the customer brief and plant requirements. Thereafter a detailed discussion of the implemented design follows. The results obtained on the shopfloor and data collected through interviews with management and staff are reported in the remainder of Chapter 4. This includes reporting on measures and procedures to assess the effectiveness in each of the stated objectives.

Chapter 5 comprises a discussion on patterns and deviations found, relating the actual to the literature reviewed. The design and results obtained are compared to predictions found in literature and conclusions are drawn on the

effectiveness of the particular designs and processes that were implemented. The chapter closes with the proposal of potential changes management might want to consider.

Chapter 6 summarises the findings and draws conclusions, but more importantly it attempts to answer the original research questions posed. Finally, it will point out the potential value of the research and suggest further research topics.

3.3.3 Data collection

Data were collected by means of interviews with staff at various levels within the organisation:

Technical Staff members were approached to assist in compiling production and operational data, this included product data, production mix and cycle and lead times. These were validated by means of plant visits and the researcher personally conducting time studies to confirm cycle times and process flow.

Members of Management were interviewed to establish logistics data such as raw material and component order lead times and mix proportions as well as forecast and production planning information. These interviews included discussions on the relationship with the customer and the operational strategy employed. Finally, the researcher confirmed, with Management, various elements of technical information that were gathered during interviews with technical and operational staff.

During plant visits, shop-floor staff was also interviewed by means of structured questionnaires (Appendix A). The purpose of these questions were to confirm the production and process data collected from management and technical staff, as well as to look for evidence or the presence of implemented Lean practices. It should be borne in mind that shop floor staff were only willing to be interviewed during production time and thus such questions had to be concise.

The questionnaire was structured as follows:

Questions 1 through 3 were used as introduction and to establish rapport.

Questions 4 through 6 and 8 were asked to establish the presence of organisational goal orientation. Dennis (2007:107-119) as well as Wilkinson & Oliver (1989) emphasise the mutual dependency between the organisation and workers and the resulting need for worker involvement in organisational goals and objectives. To a lesser extent these questions aimed to confirm figures quoted by management.

Questions 7 and 9 were asked to test the workers' basic operational and procedural awareness as well as to confirm figures quoted by management and technical staff.

In concluding the interview, the researcher then asks permission to measure and count a few basic variables like cycle times, work-in-process quantities

and reject quantities. The purpose is to finally verify actual data against quoted figures.

Finally, two project leaders, who played pivotal roles in the original design, construction and commissioning of the plant, were interviewed. (Appendix B). This was a joint interview with both project leaders simultaneously to enhance the quality of the responses. The main purpose of the interview was to get an in-depth understanding of the construction project of the Rosslyn plant. It focused on the rationale behind the location, the design and layout of the plant and particular problems and barriers that had to be overcome to ensure the success of the project.

3.3.4 Validity and Reliability

Validity and reliability of the data were ensured by repeating questions to various groups and at various encounters. Inconsistent answers from different groups or individuals were considered as indicative of non-validated data and were dismissed. Further reliability testing was achieved by personally confirming selected times and work-in-process quantities during shop-floor visits.

3.4 CONCLUSION

While various research methodologies are available, the researcher needs to select one such style to address the particular research problem. For this paper the researcher considered two empirical methods; the Ex Post Facto and the Case Study methodology. Due to the nature of the research and the

available information the Case Study technique was chosen. This allows the researcher to collect data in different formats and from different sources to compile a more complete representation of the situation.

Other more traditional techniques of research include pure qualitative and quantitative approaches. Each of these have their distinct application, but would be less suitable or practical in this situation due to the relative small size of potential respondent population and the diverse levels of knowledge and education of the population. The need for shop floor data and measurements added a further limitation on traditional approaches.

The following chapter presents the results of the research process, document interviews and data collection.

CHAPTER 4

PRESENTATION OF RESEARCH RESULTS

4.1 INTRODUCTION AND COMPANY BACKGROUND

Henceforth, the manufacturer researched in this study will be referred to, as *ABC Manufacturing,* to protect its identity for strategic reasons. It was chosen as a study case based on the very specific design of the operation.

ABC Manufacturing is an international organisation with several facilities in South Africa. Currently their manufacturing headquarters are located in Port Elizabeth. The Rosslyn facility is the most recent addition to their network of exhaust manufacturing facilities in South Africa. The plant is located within close proximity to their customer, allowing regular small deliveries.

Similar scenarios can be found in Brazil. Pires and Neto (2008: 329-330) writes about a so-called 'condominium approach' to supply chain management. They discuss four variations of supplier location and supply methodology. These range from Tier 1 suppliers situated inside the customer plant to Tier 1 and Tier 2 suppliers located in close proximity to the customer. Although the production strategies described by Pires and Neto (2008) differ in some aspects from that of ABC Manufacturing, several supply similarities were found, such as:

- the use of EDI communications;
- regular, small quantity deliveries (milkruns);

- sequential parts delivery; and
- frequent face-to-face contact between professionals from both supplier and customer.

In terms of the differences, the Rosslyn facility was designed to fit into the requirements of a particular customer, as well as the parameters of the larger supply chain. This is considered a unique scenario as the manufacturer has aligned itself very carefully with a single customer, but without the luxury of a long term contract to serve as collateral.

During interviews with senior staff in the organisation it became apparent that the plant had been designed and built (during 2004-5) with no more than a four year contract in place. The understanding was, at that time, that the contract would have been revisited after it had expired.

Although the single customer plant is not a completely unique situation in the South African automotive industry, this is unusual. ABC Manufacturing had to apply a new strategy to make the opportunity viable. Several Tier 1 suppliers in the industry apply a Kanban approach to supplying their OEM (Original Equipment Manufacturer) customers in a Just-In-Time manner. Other Tier 1 suppliers prefer the shot-gun approach and supply more than one and even many different OEM's and aftermarket customers.

ABC Manufacturing found a strategy that would allow it to supply a single customer in a Just-In-Time manner from its Rosslyn based facility, but still

maintain a batch manufacturing approach. This is significant as the manufacturer had to design its operation to be Lean enough to be profitable, flexible enough to deliver Just-In-Time and robust enough to manufacture in batches.

Most Lean literature would argue that batch manufacture is required due to long set-up times and that these setup times need to be reduced at all costs. This argument is still valid, but the Rosslyn manufacturer had managed to apply batch manufacture to its benefit. While cost and operational improvements could still be realised as a result of set-up time reduction (SMED), it is doubtful whether SMED will lead to a divergence from batch manufacturing. These benefits can be identified by assessing the customer requirements (listed below) that are imposed on the manufacturer by the OEM.

4.2 CUSTOMER REQUIREMENTS

The situation that ABC Manufacturing found itself in as a single customer supplier provided both the opportunity as well as the obligation for abiding by the OEM's prerequisites in terms of parts delivery. These prerequisites were:

- Keep at least 3 days Finished Goods Stock at all times to ensure continuity of supply.
- Maintain batch integrity by supplying according to engineering changes by date.
- Supply 10-15 units per hour in sequence based on a schedule supplied no more than 4 hours in advance.

4.3 OPERATIONAL OBJECTIVES

The customer requirements stated above had to be translated into operational objectives to support the manufacturing strategy of the organisation. Achieving these objectives had to be proven as order qualifying criteria. The objectives were interpreted as follows:

1. The supplier had to hold no less than 3 days worth of stock or roughly 750 units on the premises. This was crucial to the customer to ensure continued supply regardless of unavoidable operational problems like breakdowns and absenteeism. This meant that ABC Manufacturing had to provide for storage of these units as finished goods, which had facility and inventory related cost implications.
2. A low inventory strategy meant that upstream production had to be aligned with this aspect. It also meant that stock keeping had to be proportional to average demand.
3. Batch integrity is crucial at all times due to ongoing engineering changes and improvements. ABC Manufacturing would therefore need to clearly indicate the part number and change level on every part and preferably keep parts of a specific change level together in the storage facility. Withdrawal had to follow strict FIFO rules to remain effective.
4. Parts had to be delivered hourly, in small quantities. This necessitated finding a suitable location for the plant within a 30 minute radius to the customer. Any further would require additional transport units (and cost) to ensure a unit is ready for the next delivery.

5. Parts had to be delivered directly to the customer's assembly line and would thus need to conform to all quality standards imposed. Quality checks would need to be completed prior to the parts leaving the plant.
6. Delivery information would be sent through 4 hours prior to the required delivery. The customer does not produce in large batches and schedules actual production on a demand basis. As a result stillages need to be packed and sequenced according to this information. The time window is too short to produce the required parts and thus the parts would have to be drawn from finished goods stock. This has the added requirement that all possible variants must be available at all times. Such deliveries are to be done in stillages that will hold 10 units.

The above requirements were further subjected to additional production complexities and resulting from the product range, production mix and resource capacities. These aspects had to be taken into account in the design of the facility.

Some of the specific complexities were as follows:

1. The supplier, ABC Manufacturing, had to utilise a batch manufacturing strategy. This was due to the limitations of the production equipment. The equipment was constrained in several ways:
    a. in keeping with the low inventory strategy, ABC Manufacturing had to limit the size of batches;

b. this further necessitated frequent change-overs of production equipment;

c. it requires a change-over time of 30-60 minutes between batches;

d. batch production necessitated accurate forecasting of average demand; and

e. part demand and processing cycle times for various parts varied considerably, as is listed in the table below:

Part Demand and Cycle Times		
Product Variant	***Percentage***	***Cycle Time***
4 Cyl, Petrol	30.71%	4.7min
6 Cyl, Petrol	37.39	5.5
6 Cyl, Petrol (N51)	7.56	5.5
6 Cyl, Petrol (N54)	18.46	11
4 Cyl, Diesel	5.49	5.1
6 Cyl, Diesel	0.39	5.9
	100%	

Table 2 – Part Demand & Cycle Times

2. The low inventory strategy supported the batch integrity requirement, as this limited potential rejection of out-dated stock and it limited the time consuming process of 'flushing' of these unusable parts from finished goods inventory.

3. In-sequence delivery placed the following demands on the operation:

   a. parts of all variants had to be kept in finished goods stock as stock-out situations could not be tolerated;

   b. prior to delivery parts had to be inspected once more and then packed in stillages in sequence to match the OEM's line order; and
   c. provision had to be made for delivery delays and problems, such as traffic delays and vehicle breakdowns.

4. The OEM was running at a line-speed (takt time) of 4 minutes per unit. This was faster than any of the supplier's cycle times (see Table 2) and as such induced the need for multiple production resources on the supplier's side.
5. The supplier works two 9 hour shifts, while the customer works two 8 hour shifts.

Table 3 summarises the operational aspects that needed to be considered and put into action to ensure meeting the customer requirements.

Customer Requirements	Operational Objectives	Production Complexities / Requirements
• Keep at least 3 days Finished Goods (FG) stock at all times.	• Follow a low inventory strategy for finished goods. • Keep stock of all product variants. • Base stock keeping on demand proportions.	• Production batches kept small. • Frequent change of production batches. • Change-over time becomes critical. • Accurate demand forecast crucial. • Effective production scheduling crucial. • Cost of stock keeping & facilities. • Cycle times affect realistic batch sizes.
• Maintain Batch Integrity	• Follow a low inventory strategy for finished goods. • Follow FIFO inventory consumption. • Adhere to Engineering Change dates & requirements.	• Batches should not be mixed. • Clear distinction between batches. • Low inventory means limited rejection of 'old stock'. • Time-consuming 'flushing' of redundant batches.
• Supply 10-15 units per hour in sequence against 4 hourly call-off schedule.	• Parts drawn as required. • Parts inspected and packed in sequence. • Deliver on time to line. • Plant location within 30 minutes by road.	• All variants should be available. • Need Pack & Check resources. • Allow for delivery delays & problems. • Out-of-stock situation is not tolerated. • OEM line-speed is faster than supplier cycle time. • Difference in shift length for supplier and customer.

Table 3 - Operational Alignment

4.4 FACILITY DESIGN

4.4.1 Background to the Facility Design and Initiative

In order to obtain an understanding for the inception of the facility, the researcher interviewed two of the key players involved in the design, construction and commissioning of the plant. This interview followed the format of a simultaneous, structured interview with both managers present. The questions are listed in Appendix B, but the responses have been collated and reworded.

4.4.2 Interview with Key Design Engineers

The two senior managers were interviewed on Tuesday 2 June 2010 at 14:00 at the Port Elizabeth plant.

4.4.2.1 Project Initiative

The two managers were assigned the positions and responsibilities of Project Leader/Manager and Quality Manager on the project in 2004. They were responsible for the establishment of the Rosslyn plant as a green-fields project.

The project coincided with the OEM upgrading its facility to launch a new range of vehicles. The OEM had selected ABC Manufacturing mainly on a basis of price and was willing to let ABC supply the entire exhaust system, where previously the systems were supplied by two separate

suppliers as sectioned units. The project involved finding a site within a 30 minute radius of the OEM, raising the required buildings, equipping the facility and producing the systems.

Similar facilities have been designed and built by the parent company in Europe to supply the same OEM. The basic principle was thus not new but several unique elements differentiated this plant.

The time plan for getting the plant up and running was very short. On certain aspects the manufacturer had 9 months and on other aspects there were 12 months available before production had to start.

4.4.2.2 Design & Construction

For the construction of the storage system, managers decided to employ a mechanical design and construction contractor that was well known to and respected by the OEM. (Refer to paragraph 5.3.3 for a detailed discussion on the design of the system.) The system that was designed and installed is considered unique in certain ways, and has allowed the manufacturer to reduce building costs dramatically. It has also made control of stock much more effective than a floor-based system would have done. The final design was a combination of ideas from the contractor and the manufacturer.

The layout and design of the facility was a combination of the above requirements, but also the need to consider future expansion. The facility

was designed in a way to be easily duplicated and thereby increase the capacity of the existing facility. This was achieved by designing it to be mirrored in a second phase of the project, which has not yet been undertaken.

The guiding principles behind the design of the facility and the storage system were ultimately to ensure proper stock control. This included engineering design change control as well as quantity and quality control. The design allowed for ease of electronic stock-keeping (which has not been installed yet).

4.4.2.3 Logistics

Supplier and engineering/tooling organisations in the Rosslyn area were hard to convince to support ABC Manufacturing due to the simultaneous work load required by the OEM. The OEM had much larger orders and was a more regular client to these organisations. ABC Manufacturing had to turn to Port Elizabeth based organisations to manufacture tooling and other equipment. This increased the risk and cost of the project.

Once initial problems had been overcome, new ones emerged in the form of increased pressure from the OEM to localise supply of components. Most components were initially imported from Europe, but local content regulations were being imposed. Suppliers for pipes were found in the Gauteng area.

Scheduling was complex due to the need for batch production. This was further complicated by the delays in importing components. Raw materials stock was kept at about 14 days, while the longest (but most uncertain) forecast window from the OEM was 3 months. This allowed for orders to be placed, but accuracy was doubtful. Added to this, the nature of international shipping, import processing and domestic transport lead to numerous delays in the arrival of parts to the line.

4.4.2.4 Management

Staffing was dealt with, with more ease. Senior and junior management personnel were originally drawn from within the group. These included logistics and process staff among others. Shopfloor personnel were essentially taken over from the previous supplier and were found to be well trained, well motivated and productive. Technical staff was more problematic. The lack of available skills left the organisation with hard to fill vacancies. This, in turn, had a cost implication in terms of using outsourced skills.

Absenteeism presented a more long term concern. The size of the operation allowed it to work with a very small staff complement, however this also served to amplify the effect of any absenteeism. For example, if only two assembly staff members were absent, the plant capacity was reduced by 33%. Ongoing improvements and cost reductions have served to aggravate this amplification effect.

Regarding production related problems, the distance between the Rosslyn plant and the existing base in Port Elizabeth created some problems. Finding and securing support and supply was initially a problem, but was resolved over time.

Financing of the project was shared between group capital and South African government backing. Payback on tooling was limited to a 7 year amortisation plan.

Other management problems were limited; the most prevalent were policy induced in the form of being allowed to counter-offer on certain skills to ensure retention. This situation led to the loss of key technical people, whose skills had to be outsourced at even higher cost.

4.4.2.5 Lessons learnt

- The stock keeping time frames were found very limiting and would be increased where possible. This includes raw materials and finished goods.
- Slight layout changes would be introduced at the sequencing/ shipping area to improve efficiency of resources.
- Poka yoke (mistake proofing) devices and measures need to be added to prevent delivery errors. Currently these errors are caught in an audit bay/dispatch area prior to leaving the plant.
- The customer had been too involved in the operation to the extent that it had almost become an interference in management issues.

- A single customer operation is highly susceptible and vulnerable to customer problems increasing overall risk to both the organisation and its employees.

4.4.3 Physical/Structural Design

The manufacturer designed and installed an elaborate storage system that is based on the principle of a flow-rack. Production is based on the demand of each of the 6 main product lines with some derivatives. The so-called runners and repeaters are each allocated one or two of 8 positions on the flow-rack. This allows for adequate batch and design-change control. Strangers are kept in small quantities in separate locations on the picking floor.

Each position takes the form of a structure that resembles a tube with a capacity of 9 stillages that each holds 10 to 15 parts. Stillages of each type is presented to the picker who needs to withdraw parts of the appropriate type to prepare for each delivery to the customer.

The manufacturer receives a call-off signal every hour to be delivered to his line within 4 hours. This call-off signal lists the parts required and the sequence within which they need to be presented.

4.4.4 Production Planning and Control Design

Production control is based on traditional Push scheduling. Production orders are released by a centralised production plan based on the demand

requirements for the following two weeks. Batch sizes vary to some degree, but would typically be 1 to 2 shifts worth of production.

Intermediate and final assembly operations are disconnected by means of Work-in-Progress that is fed into a warehouse. Sub-assemblies are returned to the production floor for final assembly. In other words, traditional batch processing is practiced. As discussed above, production planning is done centrally, based on demand figures and stock availability.

Final assembly consists of three automated assembly stations. These are manned by two or three operators doing loading, unloading and rework as needed. At final assembly, each cell performs Assembly → Inspection → Rework before loading the unit into an awaiting stillage. As soon as the stillage is full (10 to 15 units) it is sent to Finished Goods Storage. Typically, subassemblies are released from stores to final assembly in container quantities.

Production planning is consequently not Pull-based; instead the manufacturer applies a more traditional Master Production Schedule (MPS) and Manufacturing Requirements Planning (MRPII) approach. This starts with a demand forecast received from the OEM and relatively large quantities of Work in Progress (WIP).

According to Stevenson (2007: 652-653), MRPII is dependant on certain data to be successful; this data include firm orders or good forecast information,

accurate product structure data and up-to-date inventory data. If any of these data is incorrect or volatile, the MRPII system could potentially fail or deliver incorrect results. For ABC Manufacturing, however, this system is currently successful in this situation for three main reasons:

1. Stable forecast: The forecast received from the OEM has been stabilised to some degree, as the product is a dependant part in the OEM's production process. By definition a dependant part is scheduled based on a 'known' demand (whether the 'known' demand is based on forecasts or actual orders, it has been specified and is now a fixed quantity), and is therefore a known and stable amount (Stevenson 2007: 635).
2. Simple Manufacturing Process: The production process is limited to three stages of which two are independent sub-assemblies and the third is the final assembly stage. (The Value Stream Map shows this more clearly.) This allows for ease of and more accurate inventory (WIP) control, leading to accurate requirement calculations during the MPS runs.
3. Product Standardisation: Item numbers of sub-assemblies are limited as much product standardisation has been implemented in the design phase. This has been achieved by using a particular silencer or catalytic converter in a number of end-item designs. This limits complexity of production and reduces the amount of WIP needed. It also improves the data integrity for engineering change control and inventory data.

An important qualification by the OEM was the need to observe engineering changes very carefully. The manufacturer has been able to do this effectively by combining four aspects of the environment.

1. Forecast window: ABC Manufacturing normally has a 3-6 month warning period in terms of engineering changes taking effect. This is sufficient to ensure tooling gets updated or the applicable component or material orders are placed. This allows for both local and import orders.
2. Finished Goods Stock: In addition to the forecast window, the three day finished goods stock limitation means the manufacturer should theoretically be able to run out any 'old' parts quickly and there-by avoid confusion and mix-ups. This also adds to the Leanness of the operation as very little scrapping of redundant parts will occur.
3. Limited product Range: The product range of ABC Manufacturing comprises about 6 variants while the storage system allows for 8 locations. This leaves at least one location per design, ensuring design-location specific storage.
4. Flow-rack design: The flow-rack has been designed in such a way as to physically prevent the insertion of stillages in amongst other older parts. This forces the first-in-first-out (FIFO) principle by only allowing the oldest parts to be drawn by the sequencing picker. In the rare and exceptional case where a required part is stuck in the middle of the 'tube', stillages can be 'flushed out' or cycled with management approval (refer to Figure 2).

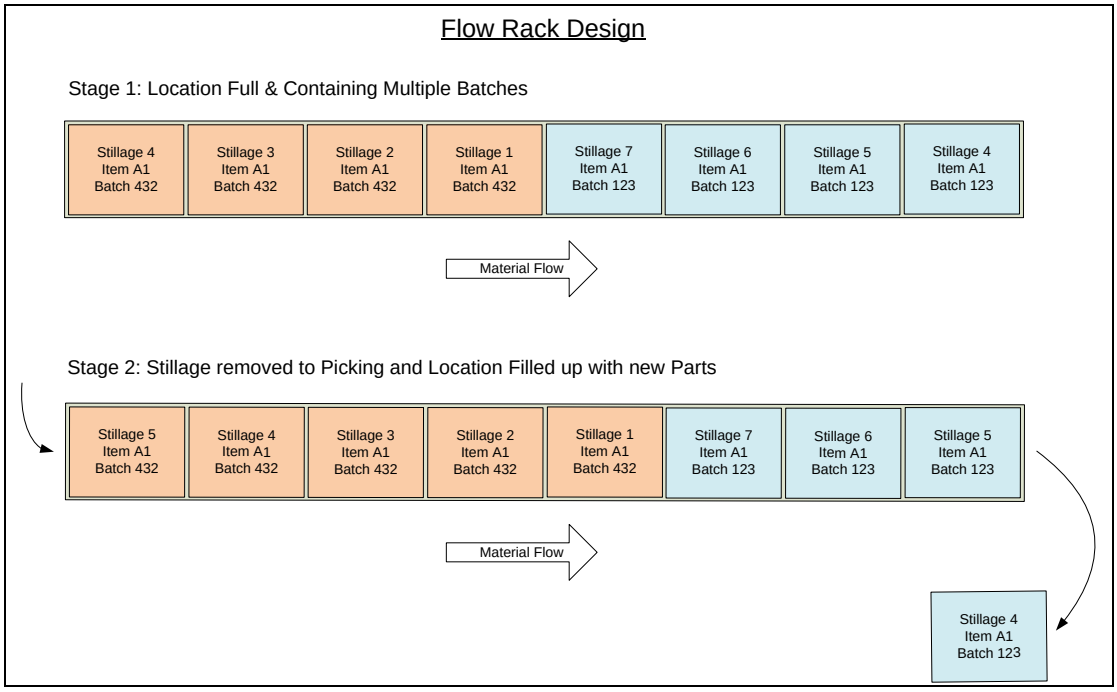

Figure 2 – Flow Rack Design

4.5 MEASURES AND RESULTS

The results of the design were confirmed by means of interviews with staff and management. These results were triangulated with actual counts and time studies in selected areas.

4.5.1 Delivery Accuracy

No reports could be found on delivery failure. It is assumed that deliveries are done on time.

4.5.2 Sequencing of parts

Management indicated that no sequencing errors have been reported. This was confirmed by sequencing staff. At this point errors are considered to be

unlikely due to the fact that stock availability is certain and requirements are received in advance. In terms of human error, mistakes are unlikely due to double checking of delivery stillages prior to leaving the plant.

4.5.3 Returns from OEM

This is supported by the previous point. No returns have been reported to the researcher.

4.5.4 Availability of Stock

Management reported that the three day finished goods stock level is maintained. An actual count of this revealed that 5 of the 64 stock positions were open, but the stillages were found in the sequencing area, being emptied into awaiting delivery stillages. This supported management reports.

4.5.5 Engineering Change Integrity (Change Control)

Change Control is managed and maintained by providing production staff with detailed production documentation. Every order is accompanied by a parts list and assembly schedule to ensure the correct components are supplied and the correct assembly configuration is applied. Operators check part and component item numbers prior to starting a batch. A first-off and last-off unit is produced and verified by quality control personnel.

The researcher noted that production staff appeared sufficiently technically literate.

4.5.6 Other measures

Cycle Times:

Cycle times were measured on the production floor and compared to production planning information and these correlated well. In some cases minor deviances were noted.

Daily Targets:

All production staff was aware of their particular daily targets, reject rates and cycle times.

Maintenance of Change Control:

Production staff members were able to identify change control deviations effectively and were aware of the correct procedure to address such problems.

Work in Process:

Work in process was replenished on an as-use basis. A single container of parts would be delivered from stores as the previous container empties out. Parts left over at the end of a batch would be returned to stores unless that part is used on the next order as well.

Down Time:

Down time data were provided for 2009. This indicates that change-over related down time was the second largest contributor during November 2009

(refer to Figure 3). This superseded downtime contributors like delays due to part shortages and equipment breakdowns. Other contributors were not clearly defined or had little impact on the total figure.

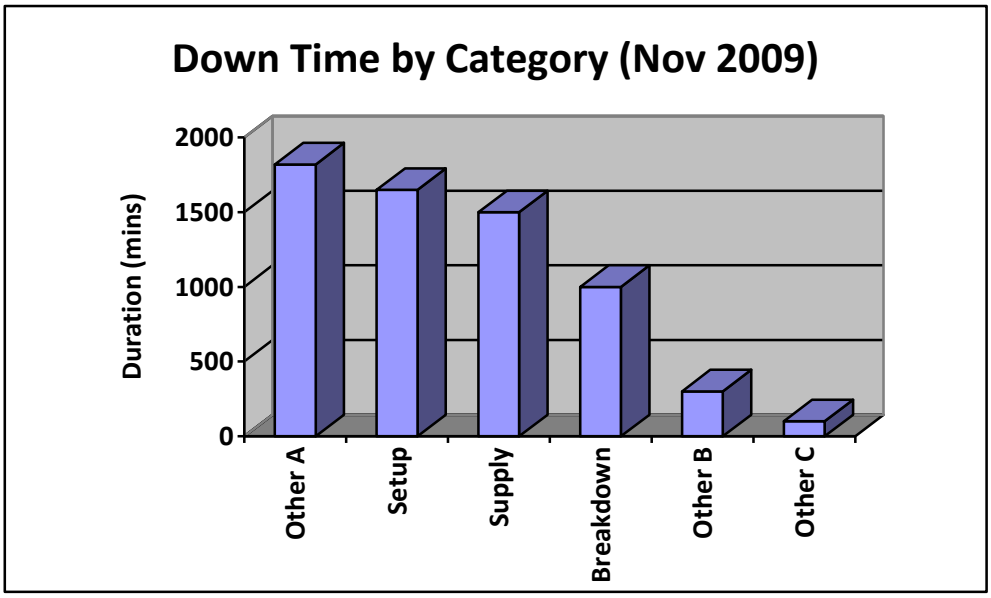

Figure 3 - Down Time by Category (adapted)

It was also found that change-overs doubled in count (Figure 4) in the months October ’09 and November ’09. This has no doubt contributed to the increasing trend in total monthly downtime over the second half of 2009 (Figure 5).

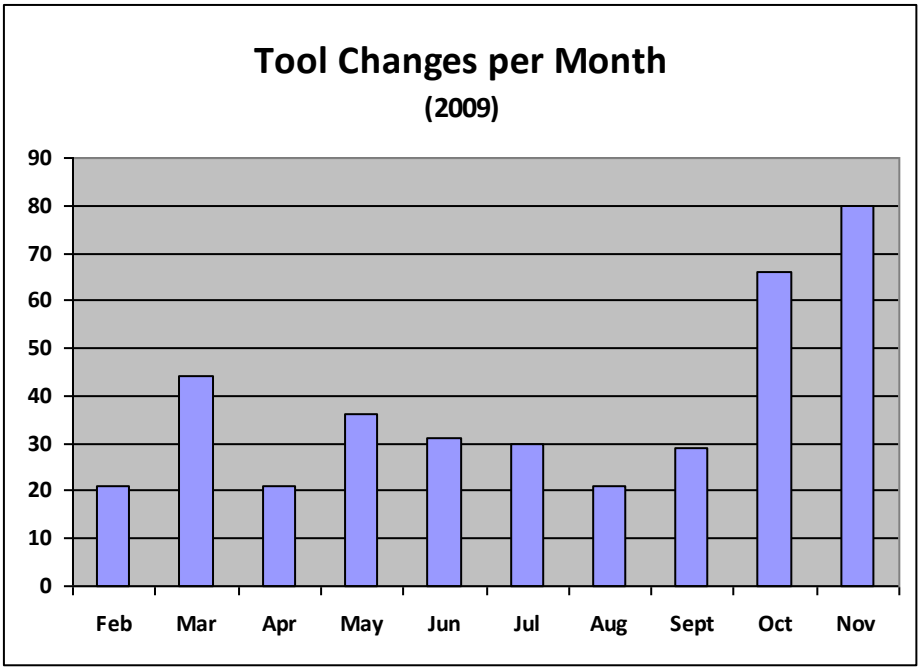

Figure 4 - Tool Changes per Month (adapted)

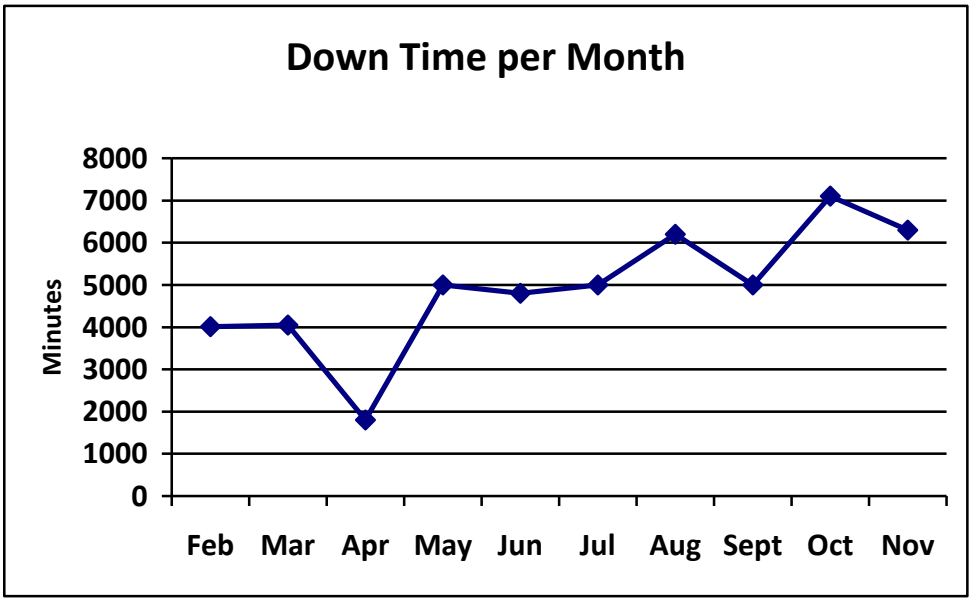

Figure 5 – Down Time per Month (adapted)

4.6 CONCLUSION

This chapter presents the data collected by means of interviews, discussions, actual measurements and reports. Various aspects of the strategy behind an aggressive launch into the automotive industry in the Rosslyn area are presented. Of these, the most noteworthy is the fact that the manufacturer designed and constructed a single customer plant in record time. This went hand-in-hand with the application of several Lean techniques to ensure they could meet the very high standards and demanding delivery requirements of the OEM.

Possibly the most challenging factor is the delivery requirements: being able to supply a range of parts in small quantities in the correct sequence with very limited finished goods stock. For this purpose a specially designed flow rack system or supermarket was built and supported with automated cells on the supply side and dedicated packers and inspectors on the demand side.

It was shown that good logistics and production planning skills and systems adds the necessary support to ensure the facility reaches its potential. The manufacturer applies Lean principles into the design of the facility and management of the plant and although these can easily be overlooked for common sense, Lean manufacturing is exactly that: sound logic applied in an unrelenting and disciplined manner to eliminate waste in all its forms in order to achieve customer satisfaction.

The next chapter compares the results presented in this chapter to some of the suggested best practices found in literature. It attempts to identify agreement with and deviation from these ideals and try to understand the reasoning behind such decisions. In conclusion, it suggests some changes based on the findings presented here.

CHAPTER 5

COMPARISON OF ACTUAL DESIGN TO SUGGESTED BEST PRACTICES FROM THE LITERATURE

5.1 CURRENT STATE OF PRODUCTION

Figure 6 shows a Value Steam Map of the particular manufacturer's process. The intention is to use this as a means to compare the process with suggested processes as found in literature.

The Value Stream Map describes the entire production process within the limitations of a single page. It follows an anti-clockwise flow and starts at the top centre indicating the origin of production and material orders. Top left to middle left indicates inbound logistics and ends in two triangles representing raw materials inventory of roughly 3 weeks. The two parallel preparation stations indicate the assembly of pipes and silencers respectively. Final assembly is buffered by 3 days of Work in Progress. Finally a supermarket provides a buffer of finished goods to fill customer orders. Customer orders are indicated top right and feed into the central production control at top centre. Although parts are pulled from the supermarket by the customer, production control is still based on a buffer-and-push system.

Current State Value Stream Map

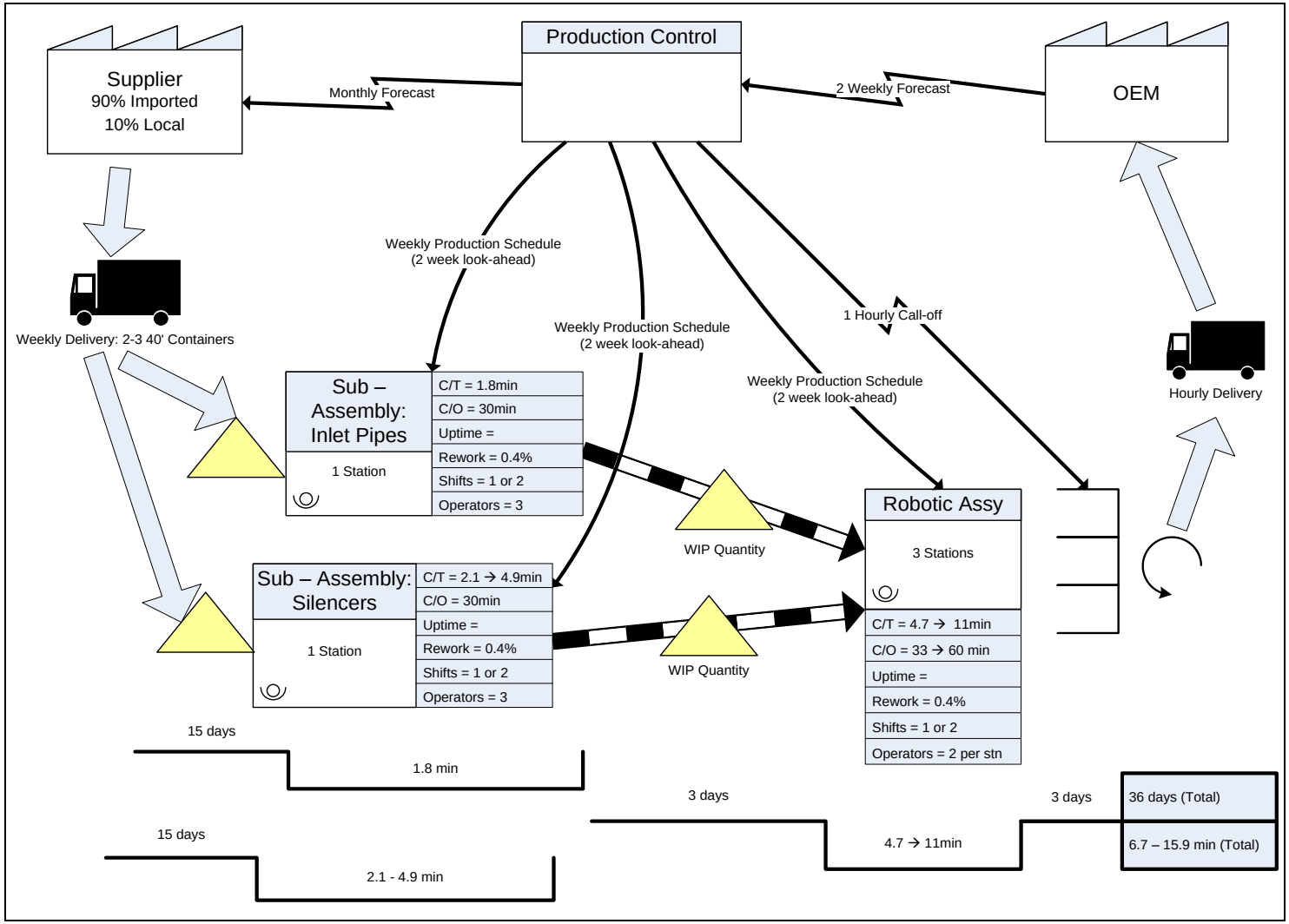

Figure 6 - Current Value Stream Map

Production control is largely forecast based. Historical demand distribution is shown in Table 4, while daily demand could differ dramatically from this.

Demand Distribution & Setup Times			
Product Variant	**Demand Percentage**	**Setup Time**	**Cycle Time**
6 Cyl, Petrol	37.39	30	5.5
4 Cyl, Petrol	30.71	30	4.7
6 Cyl, Petrol (N54)	18.46	30	11
6 Cyl, Petrol (N51)	7.56	30	5.5
4 Cyl, Diesel	5.49	30	5.1
6 Cyl, Diesel	0.39	30	5.9
	100%		

Table 4 – Part Setup Times

Based on Smalley's (2004: 15) classification of Runners, Repeaters and Strangers, ABC Manufacturing's demand has been depicted in Figure 7. According to the chart, the following classifications could be made to the parts:

A Items: (60% of demand)

- 6 Cylinder Petrol
- 4 Cylinder Petrol

B Items: (next 20% of demand)

- 6 Cylinder Petrol (N54)

C Items: (Last 20%)

- 6 Cylinder Petrol (N51)
- 4 Cylinder Diesel

- 6 Cylinder Diesel

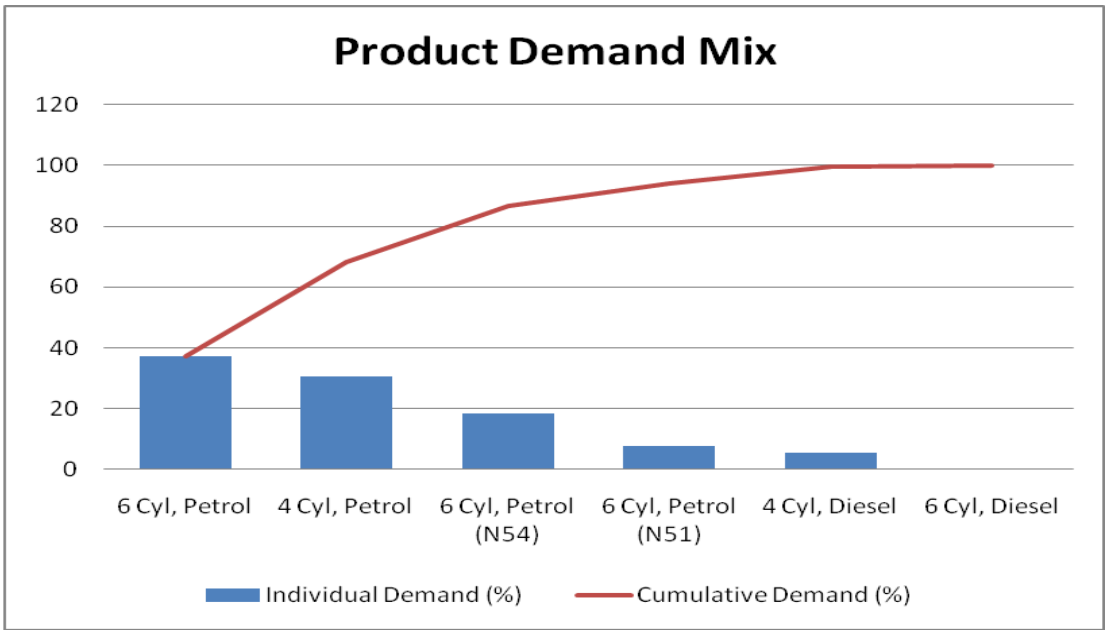

Figure 7 – Demand Mix

Although ABC Manufacturing has not made use of this classification method, in theory it would be used to specify a suitable Pull system. The details of this practice and application thereof are explained in paragraph 2.4.1.2 of this document.

5.2 COMPARISON OF ACTUAL DESIGN TO DEFINITIONS FOUND IN LITERATURE

The system in place cannot be deemed a Pull system, for a few simple reasons:

1. A Pull system is generally governed by the usage/demand on downstream processes. In this case the manufacturer employs a

central planning tool to dictate the production activities of each work-centre.

2. In a Pull system work-centers only respond to signals received indicating what to produce and how many to produce (Vollman, Berry, Whybark 1997: 79-82).

These principles (of a Pull system) would result in a production system that operates on a (almost) zero work-in-process basis, as every work-centre only produces what has been consumed. The manufacturer, instead, plans a batch, releases the materials and then returns the sub-assemblies to storage until further notice. This is typical of Push production and the opposite of Pull production.

Although this is true, the production system in place at the Rosslyn plant does lend itself to being converted to a Pull system according to the definitions offered above. In fact, the final stage of a Pull system is already in place and merely needs to be expanded.

The organisation has succeeded in separating a batch operation from a continuous operation very effectively. The finished goods store operates as a supermarket to the OEM. This practice is not uncommon in the automotive industry as well as other industries (Svensson 2004: 730-732) and is often referred to as Just-In-Sequence (JIS) production as opposed to Just-In-Time (JIT) production. These implementations are indicative of Lean principles of inventory management and supply, however, further savings are possible if these principles were extended into the production area.

The design of the inventory management system was largely dictated by the customer requirements. The first requirement specified that the customer needs to ensure a 3-day stock holding policy to protect against uncertainties of various kinds. This is called safety stock and is considered common practice in the design of Kanban and Pull systems (Gross & McInnis 2003: 9).

The OEM requires accurate delivery in terms of part types and consumes on average 250 units per day, thus the 3 day stock policy will amount to 750 units. The exact mix and sequence is only known 4 hours in advance. This means that a selection of parts must be available in the store to comply with any potential demand mix.

Table 5 offers an example breakdown of stock keeping quantities for the different part types. This shows that high demand parts are stored in greater quantities and as a particular location will only hold a maximum of 120 units, it means that more locations are allocated to the high demand parts. Some parts require more space as their size and packing configuration only allow 10 items in a stillage while others allow 15.

Stock Keeping Quantities				
Product Variant	Percentage	Minimum Quantity	Locations Used	Actual Stock
6 Cyl, Petrol	37.39	280	2	240
4 Cyl, Petrol	30.71	230	2	240
6 Cyl, Petrol (N54)	18.46	138	2	160
6 Cyl, Petrol (N51)	7.56	57	1	120
4 Cyl, Diesel	5.49	41	1	120
6 Cyl, Diesel	0.39	3	Kept Separate	15
	100%	**750**	**8**	

Table 5 – Stock Keeping Quantities

Smalley (2004: 20-23) suggests a demand based approach. This is split into three categories of Cycle Stock (supplying the daily demand), Buffer Stock (to deal with statistical deviations) and Safety Stock (to absorb production reliability problems). His approach has a stronger scientific basis, while the actual approach is primarily based on the production demand and secondly designed around the practical limitations of the infrastructure.

The existing system is not inflexible, as locations can be re-assigned to items as the demand vary. The remaining variability is currently absorbed by the centralised production planning strategy. This ensures that A items are forecasted and planned more regularly than C items and thus availability is maintained.

The main weakness of the existing system lies in the cost of expansion. Should the product range increase rapidly, the number of locations will not be able to support this and more would have to be added. This would most likely be without any guarantee of increased income to pay for the capital expended.

5.3 NEED FOR CHANGE

It has been stated that the particular type of operation is unique in that it supplies to a single customer. It also aligns itself to this customer to the extent that fluctuations in orders and product mix from the customer is felt directly on the shopfloor. Some might argue that this type of operation is folly and unsustainable. The fact, however, is that it has been operational for several years, since 2006. One could ask the following questions: Why does it survive and which principles were responsible for creating a robust enough system to withstand the turbulence of being a single customer supplier and more importantly during the time of the 2009 financial recession? Maybe more pertinently the question should be: how can this manufacturer strengthen its position in the market and how would Lean principles benefit it?

Although the production strategy cannot currently be described as a Pull system, it does lend itself to be transformed in future. The following discussion aims to highlight some avenues and considerations.

5.3.1 Possible Future Extensions

The manufacturer might decide to extend this strategy into a Pull production system and would then consider the following options as offered by Smalley (2004: 16-20).

- Replenishment Pull System – Make all to stock and hold Finished Goods (FG) of all types
- Sequential Pull – Hold no FG stock and make all to order
- Mixed Pull (a) – Only hold C-Items in FG and make A & B Items to demand (A, B & C definitions were given in Paragraph 5.1)
- Mixed Pull (b) – Only hold A & B items in FG and make C items to demand

By contractual arrangement, the manufacturer is obliged to hold 3 days finished goods and are thus excluded from using the sequential or mixed Pull (a) systems. Sequential Pull dictates no Finished Goods stock and Mixed Pull (a) requires only C Items to be kept in Finished Goods. C Items will only account for 20% of the requirements of the customer and as such will not fulfill the 3 day stock requirement. Only the Replenishment and possibly the mixed Pull (b) system might be useful.

5.3.1.1 Replenishment Pull as an Option

This option seems feasible as it requires the manufacturer to hold stock of all items and simply replenish these as they are withdrawn. Production and

supply is then effectively disconnected. On the surface it appears as if ABC Manufacturing is already utilising this option.

In reality the manufacturer is making use of centralised production planning for both sub-assemblies and final assembly. This is a result of the continued reliance on batch production in an attempt to justify long (30-40 minutes) change-overs.

5.3.1.2 Mixed Pull (b) as an Option

This would require the plant to be able to produce any mix of the A and B items (consisting of three part variants) within one hour (the delivery frequency). Considering two extreme cases for ABC Manufacturing, for simplicity sake the four hour advance notice is not factored in and only worst cases are considered:

Case 1: Should the requirement be for 15 systems of the N54, the variant with the longest cycle time, they would finish this demand in 11 minutes * 15 units = 165 minutes, or 2.75 hours. This could only be completed within the available hour if three stations were allocated to it, however, if set-up time had to be added an additional 30 minutes per station would be needed rendering the timely completion impossible (refer to Figure 8).

Case 2: Alternatively, in the case where parts from the three different variants are included in the demand; 10 units of the N54 and one each of the other variants would require 11 minutes * 10 units = 110 minutes plus 5.5 minutes *

2 units = 11 minutes totals 121 minutes (2.017 hours) production time. Add to this an additional 90 minutes for setting up for the three parts, leaves the plant short of a theoretical 31 minutes (refer to Figure 8).

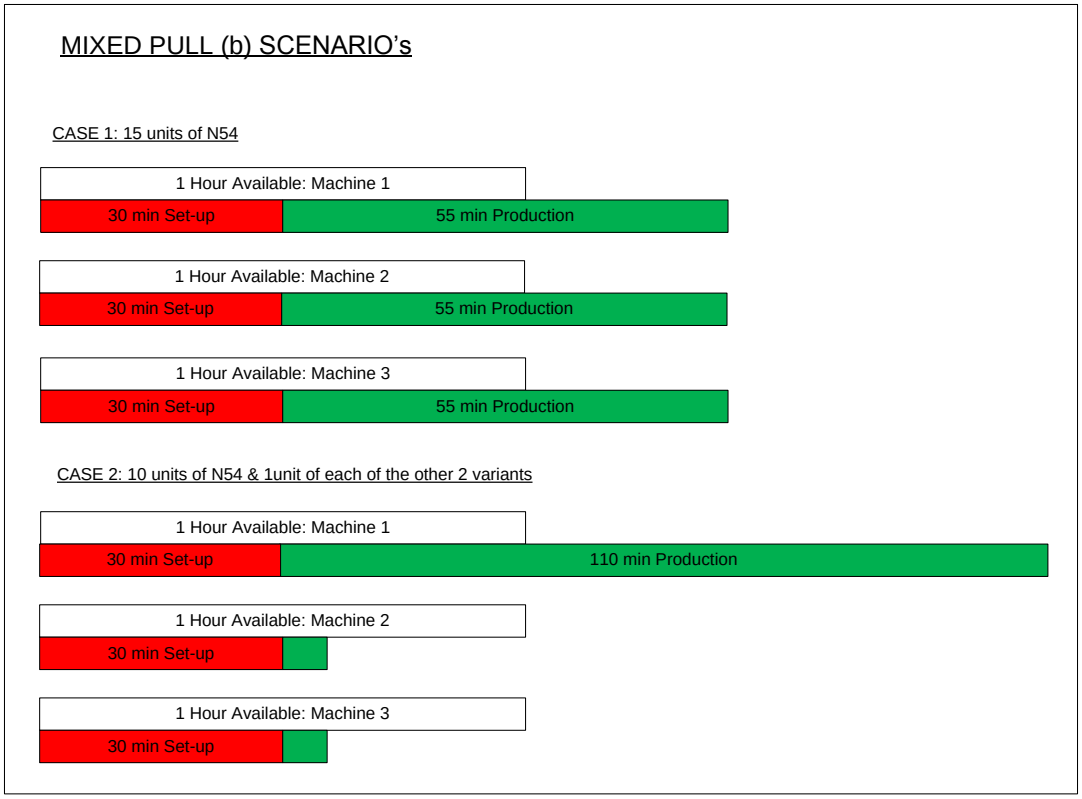

Figure 8 – Effect of Mixed Pull on Shopfloor Scheduling

Clearly setup times are problematic under this option and batch production is unavoidable until the long setups have been dealt with. Smalley (2004: 33-37) confirms this when he states that the three prerequisites for a Pull system are matched cycle times for the different parts, reduced set-up times for all parts and a suitable pitch interval. The impact of this on ABC Manufacturing is discussed in detail in section 5.3.3 below.

5.3.1.3 Suggested Option

The Replenishment Pull option is superior. The current system quite closely resembles a replenishment Pull system as it is making everything to stock. Although parts are currently replenished by batches of anticipated parts (Push) rather than parts demanded by the customer, the manufacturer could apply one of two possible replenishment strategies instead:

- The first option would see them producing in stillage-sized quantities (a variation on the pack-size as described by Smalley (2004: 34-35)). This would also require a very short change-over time and might not be immediately feasible.
- The second option would apply some of the ideas of Gross & McGinnis (2003: 72-85) where various parts are assigned minimum order quantities. At the point where this quantity is reached, a batch (and a change-over) is ordered. This means that batch production is maintained, but assembly batches are released based on finished goods inventory status (or demand) rather than on forecasted figures. The system thus changes from being predictive to being reactive.

Either of these would then see resulting orders being relayed up the production stream till it reaches purchasing in typical Kanban fashion. The main advantage here is that the shopfloor becomes self-controlling. Imported parts and parts with long lead times can still be ordered based on the three month forecast window.

5.3.2 Appointment of a Pacemaker

According to Smalley (2004: 30) the pacemaker in a replenishment Pull system will most often be the final assembly. The purpose of the pacemaker is to regulate the speed of production and dictate the mix to the rest of the plant. This implies that there needs to be an amount of stability at the pacemaker for it to be successful. Smalley (2004: 33-37) states three main pre-requisites for achieving this stability. These are:

- work content differences between different part should be minimal,
- change-overs between parts should be insignificant, and
- a Production Pitch Interval should be put into action.

5.3.3 Production Levelling at the Pacemaker

None of the above requirements have been put into practice at ABC Manufacturing.

5.3.3.1 Work content differences

The difference between the shortest and the longest cycle times is as large as the shortest cycle time itself. This in itself will present the manufacturer with some problems, but could be resolved by applying variable pack-sizes for various parts. For example, the N54 system has a cycle time of 11 minutes, while most others are around 5.5 minutes. There-fore if a pitch of 110 minutes is determined, it will allow the production of ten N54's or twenty of any of the other variants. The current cycle times are thus incompatible with the delivery quantity of ten to fifteen units.

5.3.3.2 Insignificant change-over times

Careful consideration of the pitch, cycle-time and pack-size will be needed to allow different systems to be fully compatible. Once this has been decided one needs to assess the change-over times. Currently these range between 30 minutes and an hour. This will be too long in a Pull situation and a careful study of this will be needed. Some modifications to equipment are usually required to make such a study successful. One possible approach to this might be to group parts by cycle time, thus creating stability within the cell as opposed to within the plant as a whole.

According to Shingo (1989: 211-224) the implementation of SMED, or change-over time reduction, is one of the first tasks in implementing the Toyota Production System (TPS) Shingo does not describe the benefits of this, but rather points out that it is an essential process to be able to respond to orders and that "..no transition to Toyota Production System can occur without drastic reductions in setup times" (1989: 215).

5.3.3.3 Production Pitch Interval

Material and component feeding to lines should be modified as well. Currently, large containers of parts are delivered to the line and used until empty, or returned to stores if not. Instead, a timed delivery (Pitch Interval) of components will be needed. This will avoid running out of parts on the line or having to return parts, both of which resemble waste. In a typical Lean situation a material handler is employed to feed lines with the correct part and number of parts as needed. Completed sub-assemblies will also not be

returned to stores as is done presently, but rather be fed to the downstream processes, on demand. This method of parts delivery to work stations is described by Rother & Shook (2008: 76) as a load leveling technique. Other terms include the Heijunka method of parts delivery.

The reduction of on-line parts will lead to opening up of space on the floor. This could be applied to installing new equipment or simply to store change-over tools/trolleys at the machine/workstation.

5.3.4 Quality Assurance

Any Pull system requires that no unacceptable parts are passed onto the next station. Daugherty, Rodgers and Spencer (1994) have found empirical proof of the need for improved quality and the implementation of quality management programs to ensure the success of similar Pull systems.

Evidence of such quality awareness was found at ABC Manufacturing. Quality problems are eliminated by means of a variation on the Quality at Source principle. Each cell does its own inspection and rework. Inspection is done by plugging all open ends of the exhaust system and pressuring it. Leaks are found by ear, feel and instrument and then repaired.

However, during the research visits, no recording and/or feedback was done of rework problems. Had this been done, the information could be used to make adjustments to the welding programs and in turn close the feedback

loop. This might then result in a cycle time reduction. An opportunity for standardisation and continuous improvement was thus missed.

5.3.5 Other Lean Techniques Suggested by Literature

Literature offers numerous techniques and tools to improve a wide range of aspects of the organisation, but the researcher would advise against too much too soon. Yet if there had been one technique that might be worth looking into, it would be Total Productive Maintenance (TPM). TPM is a program that finds and implements proactive and cost-effective methods and habits to maximize the effectiveness of equipment. The already vulnerable position the manufacturer finds itself in amplifies the need for reliable equipment.

For November 2009 breakdowns featured only as a fourth biggest cause for downtime, but equipment wear will see this figure increase over time. It would be wise to implement a system whereby equipment is ‘looked-after’ on a continuous basis. This need is even further emphasised under the assumption that a Pull system should be implemented. The need for interruption free production would be even stronger in this case. The old adage applies: “A stitch in time will save nine.”

5.3.6 Summary

In summary, Table 6 shows a comparison of the current production control aspects to proposed applications.

Based on the findings above a transition from the current to a Replenishment Pull, offers the smoothest option into Lean manufacturing. Other options are possible, but would lead to more disruptive changes and/or be more capital intensive.

Comparison of Current and Proposed Applications		
Aspect	**Actual**	**Proposals**
Type of Pull System	Centralised Push	Replenishment Pull
Takt Time	No	Cycle Time < Takt Time
Change-over Time	30-60 minutes	SMED
Pack Size	Batches	Feasible / Practical
Pitch Calculation	None – Batch Production	Based on Pack Size
Stock Keeping	Customer Specification	Based on ABC Analysis
Delivery Accuracy	Call-off Schedule	Kanban
Team work	Production Planning	Heijunka
Production Levelling	Production Planning (MRP)	Heijunka
Pacemaker	Final Assembly	Final Assembly
Layout	Cellular	Not Specified
Maintenance	Breakdown/Preventive	TPM

Table 6 – Comparison of Applications

5.4 CONCLUSION

The purpose of this chapter is to identify the compliance or lack thereof between the practices in place at the plant and knowledge derived from literature.

A pure Lean facility will practice ‘Pull production’ for various reasons, but mainly to achieve flexibility and reduce waste. This was one of the main ‘deficiencies’ identified by this study. Reasons are offered and the resulting complications and compensations are discussed. Yet, even though Pull was not achieved, the plant has managed a reasonable measure of flow and definitely managed to satisfy their customer.

The normal evidence for continuous improvement (suggestion schemes, team meeting areas and performance displays and visual management signage) was strikingly absent from the plant, so it leads one to assume that the drive for perfection is absent too. Yet, shopfloor staff who were interviewed showed some dedication to process ownership.

At a more technical level, long (relatively speaking) change-over times have not been rigorously targeted as improvement opportunities. If this had been done, production planning would have been a simpler and more routine exercise. Currently planning is highly dependent on forecasts and the accuracy of such forecasts is indicative at best. Reducing cycle times or grouping of parts into families present further opportunities to management. These too, it would seem, have been left unchecked.

While not capturing these opportunities do not spell imminent demise, the product range is, reportedly, becoming more diverse and this will bring with it further complications. TPM was listed as a last best practice suggestion to assist in curbing future production downtime.

The next chapter concludes the study by revisiting the problem statement and research questions. It draws some conclusions and makes final recommendations. It finishes off by considering the contribution of this paper from a research point of view.

CHAPTER 6

CONCLUSIONS & RECOMMENDATIONS

6.1 REVISITING RESEARCH OBJECTIVES

6.1.1 What does literature reveal about the relevant topics?

Chapter two summarised the relevant literature in terms of the philosophy and practises of Lean Manufacturing as well as the use of supermarket scheduling systems.

6.1.2 How was the project initiated and implemented?

Chapter four offers an in depth discussion on the rationale and the implementation of the project.

6.1.3 Have the operational objectives been met?

It was demonstrated that the objectives could be and have been met. Moreover, the manufacturer aligned its process and facility in such a way so as to coincide with the demands of the customer, by physically building a storage facility to allow for and limit the amount of finished goods produced. A similar focus on customer needs have been identified and pursued by the designers and followers of the Toyota production system for many years (Dennis 2007: 19).

The process of limiting the amount of stock keeping is in line with other Lean principles such as the creation of flow, and the elimination of waste.

Sequencing and timeous delivery of parts became much simpler as a result of the above stock control system. This meant that the subsequent objective, of engineering change control, could be met without additional strain on the manufacturing side of the operation.

Engineering change control was achieved with greater ease than would have been the case had the manufacturer opted for more standard storage configurations. Standard and static warehouses are infamous for mix-ups and confusions. Although pick-by-light and other scanning options have made these more productive in recent years, the dynamic storage or flowrack tends to limit the possibility of making mistakes (poka-yoke) to a large extent.

Although the objective of the manufacturer was never to become a Lean supplier or to actively pursue Lean initiatives, it did apply some Lean principles and techniques. These have been practical and applicable to the situation the manufacturer was in.

6.1.4 What barriers and obstacles were encountered?

The first and most obvious barrier the manufacturer had to contend with was the distance and their newness to the specific region. This had been overcome by relocating a senior staff member and project leader to the area. His objectives included managing and implementing the project as well as appointing project contractors and other staff to assist in bringing the project to completion.

Possibly the most important barrier was the ability to build a network of support in the area. This could be ascribed to availability, micro-cultures, mutual lack of history and confidence among customer and support suppliers.

The simultaneous upgrade of the OEM's facility to introduce a new vehicle left a support vacuum. This was unexpected and left the manufacturer to find alternative sources, some of which had to be brought in from afar.

Perhaps the most difficult barrier was that of the time-frame. ABC Manufacturing effectively had nine months to design, build and commission a fully functional plant.

Finally, staffing issues presented constraints in certain cases. The need for highly qualified technical staff is critical to the particular type of business. This is further complicated by the fact that these personnel are mobile and in high demand from other organisations. Policy and operational requirements were found to be in conflict in these cases, leading to increased costs. In addition, very lean staffed operations left little margin for absenteeism and this presented the occasional problem.

6.1.5 What lessons have been learnt in the process?

6.1.5.1 Problems

The risks involved in running a single customer operation are high from a survival point-of-view. This was known before-hand, but experience has

added to the learning. As such, this led to additional and unforeseen operational problems. Such problems included the following:

- The inability to use production resources flexibly. Once the finished goods quota was full, production staff was forcibly idle. No TPM or 5S programs were in place to ‘keep staff busy’. Policies also would not allow staff to be sent home or to ‘make up’ such losses with overtime on other days.
- Production speed at the customer dictated that of the supplier. During the 2009 recession, the customer opted for short-time production, which had a direct effect on the manufacturer.
- The involvement of the customer in the business was at times interfering and directive more than assisting and supportive.

6.1.5.2 Successes

The use of respected and trusted support made the design and construction of the storage system not only possible but also successful. The particular manufacturer has done much work for the customer as well and was therefore a first choice suggestion from the customer.

Finally, the close-knit and contractual relationship between the customer and the manufacturer proved to ensure a highly successful partnership to date. The size of automotive OEM’s are often cited as overwhelming and directive, but this case shows that it is possible and essential to create a basis of understanding on which to build the partnership.

6.1.6 What changes could be recommended?

The following changes have been recommended:

1. Reduction of change-over times will save some production time, but more importantly will open up several new avenues of operation. One such avenue will be the introduction of Pull production. This will, to some extent, alleviate some resource utilisation concerns.
2. The introduction of a TPM program and even a 5S program will allow for smoother production, better ergonomics and better flow with less interruption and downtime.
3. Specific policy and union agreement changes were identified that would further allow more flexibility in dealing with the pressure of a single customer supplier.

6.2 CONCLUSIONS

6.2.1 Operational Success

The findings of this study points to the success of the facility in meeting the demands of the customer. These demands have been conflicting in some ways and challenging in others. The solutions that were found and implemented have been unconventional and creative in many ways. Certain challenges are, however, still to be resolved.

It can be safely said that the project was successful.

6.2.2 Research conclusions

The results and findings indicate that the design has been successful in delivering the intended requirements. From a research point of view, however, this study supports the hypothesis that selected Lean manufacturing techniques can be applied, during the design phase, of the facility. In addition this also supports the hypothesis that these principles are effective in delivering the stated customer requirements.

6.3 RECOMMENDATIONS

Some recommendations have been made in order to allow the manufacturer to further improve its competitiveness and cost-effectiveness. These were mostly around Lean technique implementations and typically based on literature found on the topic. It is clearly understood that literature and practice are often at opposing ends of the same spectrum and as such not always directly applicable to each other.

6.4 CONTRIBUTION OF THIS RESEARCH

This study is limited in some respects. It only focuses on the automotive industry and avoids the complexities of the greater manufacturing sector of South Africa. It also only studied a single operation/facility of a single group within the automotive sector.

The value of this highly focused study lies in the peculiarities of this particular manufacturer and the resulting lessons that could be learnt in the process. The feasibility and entire production model of this facility is based on a single

(albeit large) customer. It survived the onslaught of a very destructive recession, while the global automotive market took a dramatic beating.

In a nutshell, the success of this facility is considered to be the result of a focused process design, good project management, good operations management and finally strong relationship management with the customer.

Although Lean principles were applied in the design of the facility and the relationship with the customer, the researcher found that very little popular Lean techniques were implemented. These findings might allude to a possible link to sustainable Lean implementations, a topic that has been written about by Liker (1998).

REFERENCES

AEIC. 2009. Automotive Trade Data. Looking @ Publishing and Communication.

Besterfield, D.H., Besterfield-Michna, C., Besterfield, G.H. & Besterfield-Sacre, M. 2003. Total Quality Management, 3rd edition. New Jersey: Pearson Education.

Bicheno, J. & Holweg, M. 2009. The Lean Toolbox. 4th edition. Buckingham: Picsie Books.

Black, J.T. & Hunter, S.L. 2003. Lean Manufacturing Systems and Cell Design. Society of Manufacturing Engineers. Michigan.

Carreira, B. 2005. Lean Manufacturing that Works. New York: Amacom.

Daugherty, J., Rogers, D.S. & Spencer, M.S. 1994. Just-in-Time Functional Model: Empirical Test and Validation. International Journal of Physical Distribution & Logistics Management. volume 24, no. 6, pp. 20-26. MCB University Press Limited

Davis, M.M. & Heineke, J. 2005. Operations Management Integrating Manufacturing and Services. 5th edition. New York: McGraw-Hill.

Dennis, P. 2007. Lean Production Simplified. 2nd edition. New York. CRC Press.

Domingo, R., Alvera, R., Peňa, M. M. & Calvo, R. 2007. Materials flow improvement in a lean assembly line: a case study. Assembly Automation, volume 27, no. 2, pp. 141-147

Goldratt, E.M. & Cox, J. 1992. The Goal : A Process of Ongoing Improvement. 2nd Revised Edition. Cape Town: North River Press.

Gross, J.M. & McInnis, K.R. 2003. Kanban Made Simple, New York: Amacom.

Gross, W. & Shichman, S. 1987. How to Grow an Organisational Culture. Personnel. September, pp. 52-56.

Hitt, M.A., Ireland, R.D. & Hoskisson, R.E. 2005. Strategic Management. 6th Edition. Mason: Thomson South-Western.

Leedy, P.D. & Ormrod, J.E. 2010. Practical Research Planning and Design. Boston: Pearson.

Liker, J.K. 1998. Becoming Lean, Inside Stories of US Manufacturers. Portland: Productivity Press.

Liker, J.K. 2004. The Toyota Way. New York: McGraw Hill.

Liker, J.K. & Meier D. 2006. The Toyota Way Fieldbook; A Practical Guide for Implementing Toyota's 4Ps. New York: McGraw-Hill.

Louis, R.S. 2006. Custom Kanban. New York: Productivity Press.

Mahoney, R.M. 1997. High-Mix Low-Volume Manufacturing. New Jersey: Prentice Hall.

Mouton, J. 2005. How to succeed in your Master's & Doctoral Studies: A South African Guide and Resource Book. Pretoria: Van Schaik.

NAAMSA. 2010. Quarterly Review of Business Conditions: Motor Vehicle Manufacturing Industry: 1st Quarter [Online]. Available: http://naacam directory.webhouse. co. za/site/awdep.asp?depnum=32917. [Accessed 21 May 2010].

Nash, M.A. & Poling, S.R. 2007. Improving Quality through Lean Concepts. Quality. p.24-25.

Ohno, T. 1982. Workplace Management. Cambridge: Productivity Press.

Pieterse, J.J., Van der Merwe, K., Lourens, A. Murray, A. & Louw, A. 2010. Implementing Lean in South African Industry. Port Elizabeth: Trilean.

Pires, S.R.I. and Neto, M.S. 2008. New configurations in supply chains: the case of a condominium in Brazil's automotive industry. Supply Chain Management: An International Journal. volume 13, no. 4, pp. 328-334

Rother, M. & Shook, J. 2008. Learning to See: Value-stream Mapping to Create Value and Eliminate Muda. Cambrigde: The Lean Enterprise Institute.

Santos, J., Wysk, R. & Torres, J. M. 2006. Improving Production with Lean Thinking. New Jersey: Wiley.

Schonberger, R.J. 1982. Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity. New York: The Free Press.

Senge, P. 1990. The Fifth Discipline: The Art & Practice of the Learning Organisation. New York: Doubleday Currency.

Shingo, S. 1989. A Study of the Toyota Production System: From an Industrial Engineering Viewpoint (Produce What Is Needed, When It's Needed). Cambridge: Productivity Press.

Smalley, A. 2004. Creating Level Pull, A Lean Production-System Improvement Guide for Production-Control, Operations, and Engineering Professionals. Cambridge: The Lean Enterprise Institute.

Statistics South Africa. 2010. Gross Domestic Product: Fourth Quarter: 2009 [Online]. Available: http://www.statssa.gov.za/publications/P0441/P0441 4thQuarter2009.pdf. [Accessed 10 September 2010].

Stevenson, W.J. 2007. Operations Management. 9th edition. New York: McGraw Hill.

Stevenson, W.J. 2009. Operations Management. 10th edition. Boston: McGraw Hill.

Svensson, G. 2004. Key areas, causes and contingency planning of corporate vulnerability in supply chains; A qualitative approach. International Journal of Physical Distribution & Logistics Management. volume 34, no. 9, pp. 728-748

Vollman, T.E., Berry, W.L. & Whybark, D.C. 1997. Manufacturing Planning & Control Systems. 4th edition. Boston: Irwin/McGraw Hill.

Wikidepia. 2010. Empirical Research [Online]. Available: http://en.wikipedia.org/wiki/Empirical_research. [Accessed 7 July 2010].

Wilkinson, B. & Oliver, N. 1989. Power, Control and the Kanban. Journal of Management. volume 26, no. 1, pp.47-58

Williams, S.J. 2006, Managing and Developing Suppliers: Can SCM be Adopted by SMES? International Journal of Production Research. Volume 44, no. 18-19, pp. 3831-3846

Womack, J.P., Jones, D.T. & Rice 1990. The Machine that Changed the World. New York: Rawson Associates.

Womack, J.P. & Jones, D.T. 1996. Lean Thinking. New York: Simon & Schuster.

APPENDIX A: QUESTIONS POSED TO SHOP FLOOR STAFF

1. What is your name?
2. How long have you been working at this organisation?
3. What is your job description?
4. Do you know the daily production targets? Can you give them?
5. Do you know the (average) reject rate at your station? Can you give it?
6. Do you know the total reject rate for the plant? (going to the OEM?) Can you give it?
7. What is the cycle time at your station for this part?
8. How often are parts delivered to the OEM?
9. Batch numbers (Engineering Changes) are important to the customer.
    a. How do you recognise them?
    b. What do you do when you detect a problem with this?
10. May I take some measures/counts please?
    c. Work in Process
    d. Cycle time
    e. Reject Count

APPENDIX B: INTERVIEW WITH KEY PROJECT LEADERS

1. What were your respective responsibilities on the project?
2. Could you expand on the origin of the project? (Initial concept, Need identification, Feasibility studies, etc)
3. What were the main concerns, problems to be overcome during the initial stages of the project?
4. Did these change dramatically as the project progressed? How?
5. Please tell me more about the people/labour/union issues?
6. Production issues?
7. Financial issues?
8. Management issues?
9. Supplier / Contractor issues?
10. How did the design of the facility come about?
11. Did certain specific principles or objectives govern the design?
12. If you were to design another facility, what would you do the same?
13. What would you do differently?
14. If there was one/two things you would remember (take away) from the experience what would that be?