Final Year Project: Final Draft

Implementing Lean principles and defining the requirements for a bar coding system at British Aerospace Land Systems SA.

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GLOSSARY

Term	Abbreviation	Definition
Enterprise Resource Planning	ERP	ERP is a way to integrate the data and processes of an organization into one single system (Internet: Tech-Faq).
Just-in-Sequence	JIS	When component parts arrive at a production line just moments before they are used on the production line and in the right sequence in which they will be used (Internet: Modern Materials Handling, 2007).
Just-in-Time	JIT	"JIT delivers the right items at the right time in the right amounts (Liker, 2004: 23).
Kaizen	Kaizen	Continuous Improvement of processes and procedures throughout an organization (Liker, 2004: 283-284).
Kanban system	Kanban	"Cards instructing the production line to make a certain quantity of a certain end product (Liker, 2004: 126)."
Lean Manufacturing	LM	Continuous elimination of all waste resulting in a system of value added activity (Internet: Best Management Articles).
Supply-Chain Operations Reference-model	SCOR	"SCOR combines elements of business process engineering, metrics, benchmarking and leading practices into a single framework (Bolstorff & Rosenboom, 2007: 2)."
Bill of Materials	BOM	"The bill of materials (BOM) file contains the complete product description, listing not only the materials, parts and components but also the sequence in which it is created (Chase, Jacobs & Aquilano, 2006:637)."

EXECUTIVE SUMMARY

Lean Manufacturing is a well known phrase and buzz word all over the world and in the majority of business environments, especially in manufacturing plants. LM is recognized throughout the world and especially in the manufacturing industry. Although a lot of industries and organizations have yet to succeed in adopting lean, these organizations are aware of LM. Toyota is considered to be the pioneers of LM; this is evident looking at their performance and market share. Looking at Toyota`s success story confirms LM to be powerful methodology to improve an organization.

Land Systems OMC is seeking to improve their current business policies, processes and procedures by implementing applicable LM principles. Land Systems OMC is a division of BAE Land Systems South Africa and designs and assembles military armoured vehicles. Due to increased market share over the recent years OMC are experiencing rapid expansion. As a result of the vast production requirements, they are experiencing a lot of capacity and production constraints. Needless to say it is crucial for OMC to run their facility as best as possible with the available resources they currently have.

A step in the right direction will be to evaluate their current business processes and seek ways where implementing LM principles will be applicable to improve their plant and business.

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1. INTRODUCTION AND BACKGROUND

BAE Systems Land systems is an international company, orignially found in Britain, that manufactures and designs military equipment. Their manufactured goods ranges from large aircrafts, fighter planes, tanks, combat vehicles, submarines, advanced weapon systems and even large aircraft carriers and ships. Over the years, since their existence they expanded all over the world with many production plants, designing and manufacturing all kinds of military equipment.

Land Systems OMC situated in Benoni, Gauteng, is a division of BAE Land Systems South Africa, which is part of BAE Systems Land Sytems, an international armourments group. The main focus at OMC is to manufacture tanks and mine protective vehicles for local and international customers.OMC don`t just manufacture these products, but are also responsible for their maintenance, refurbishment and customer support. OMC have very large and complex supply chain network as well as customers all over the globe. Because OMC source and deliver locally and globally, their supply chain network is not very easy to manage and to stabilize. The company operates mainly in a Make-to-Order environment, but because of the customer support division they use forecasting models for most of the spare parts they order and distribute. Another big factor is that, although they operate in a Make-to-Order environment, numerous critical parts used in the production process have long lead times, which makes it extremely difficult to monitor and control.

For OMC to compete and successfully manage the rapid expansion, they need to look at lean principles such as JIT, JIS, Kanban, 5S, SCOR and technology approaches such as bar coding. Briefly explaining the principles mentioned above will have the following effects on OMC and is the reason why it will be worth their while to implement them.

- JIT will ensure OMC that the products will only be on the premises when required to complete the production process for that specific task, and at that specific time. This can have a substantial impact on their inventory management. It will reduce a lot of unnecessary line side inventory that will in turn create more space for production, as well as bring forth improved inventory management control and visibility (Liker, 2004: 126).
- The JIT methedolgy will be driven by a Kanban system, which implies that orders and buyoffs of products is managed using signs to expedite or order new

components. This is a simple method that will be described in detail in the literature study (Liker, 2004: 126).

- The 5S principle will ensure that all the tools, parts and equipment have a dedicated location. Besides that all these tools, parts and equipment has a dedicated location it must always be visible, well organized and in the assigned location. The 5S approach will make it easy to note when something is missing or in the wrong place and can be addressed as quick as possible. (Liker, 2004: 126).

- Bar coding systems will reduce unnecessary manual material handling, increase picking, binning and expediting accuracy and tracking possibilities as well as inventory management.

- SCOR will form the basis of the supply chain management method because it is a tool that helps describe all the supply chains and how to differentiate and prioritize them (Bolstorff & Rosenboom, 2007: 2).

Thus implementing LM principles can lead to manage OMC's current expansion and further improvements might also be obtainable on a long term basis project.

2. PROBLEM STATEMENT

Over the last 4 years OMC has experienced rapid expansion and increased demand levels; however their current processes can no longer cope with the increase in customer demand. Because their processes are over constrained and insufficient with the increase in customer demand, they are experiencing the following problems in the organization:

- Increased inventory levels (in warehouses and production)
- Poor visibility of materials
- Lack of control over materials
- Poor material flow patterns
- Poor production productivity and efficiency
- Unbalanced production lines
- Lost materials because of poor visibility
- Lost time due to poor material placement and visibility
- Material shortages

OMC is currently designing a new Electronic Resource and Planning (ERP) system to support their current business processes to cope with the increased capacity requirements. In addition to the new ERP system they seek an integrated solution to reduce inventory, increase material tracking and visibility as well as eliminating manual paper driven processes.

3. PROJECT AIM

The project aim is to analyze and evaluate OMC's current business policies, processes and procedures regarding procurement and material handling. After the current processes have been charted, formulated and evaluated, proposals to restructure these procedures using LM principles will be formulated, evaluated and implemented. The main purpose of implementing LM principles will be to reduce the quantity of line side stock, reduce obsolete stock increase the material expediting processes. This will lead to great financial savings per project.

The following issues could be addressed and improved:

- Reducing lead-times at goods receiving department by improving processes and eliminating manual processes.
- Increasing material visibility by tracking material through the entire manufacturing process with Bar-coding and eKanban systems.
- Reducing overall inventory at OMC by using Kanban principle to manage inventory and drive procurement process via electronic Kanban system.
- Increase the visibility of parts being stored in multiple locations.
- Redesign the current layout of the facility at OMC for improved material flow and visibility.
- Introduce a proactive alert system on non-conforming part numbers and products.
- Identifying and grouping of parts to determine the delivery frequencies as well as the necessary arrangements that needs to be made with suppliers.
- Improve material management with bar coding procedures linking information directly to the ERP.
- Eliminate unnecessary material from site when not needed at the time

4. PROJECT SCOPE

The project scope is to propose and evaluate LM principles that will fulfill the requirements of the new ERP system that is currently being designed and developed. These principles include techniques such as JIT, JIS, 5S, Kanban and new technologies that are available and applicable such as bar coding.

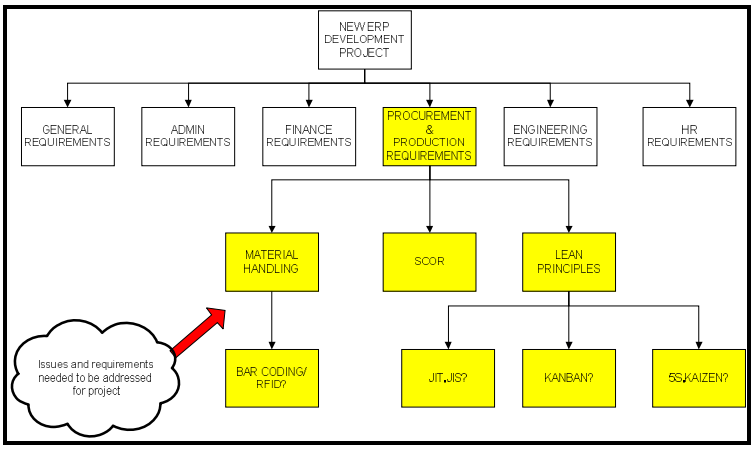


FIGURE 1: PROJECT ARCHITECTURE

5. DELIVERABLES

The desired outcomes of the project will be:

- Design, developing and implementation of a manual kanban process
- Use the manual kanban process to develop and design an eKanban system, driven by bar codes, linking actual production rate to ERP and MRP.
- Develop bar coding requirements-processes and equipment
- Introduction of a Just-in-Time environment and start implementing lean principles(long term project-start initiating)
- Change the current push system to an integrated pull/push system.
- Reduced line side inventory – smaller batch sizes, increased replenishment frequencies.
- Improved Materials Handling department
- Improved material visibility throughout the whole organization.
- Elimination of unnecessary material on site when not needed immediately.
- Use lessons learned in project to strive for continuous improvement opportunities

CHAPTER 1: LITERATURE STUDY

LEAN MANUFACTURING

Because there are numerous definitions for Lean Manufacturing (LM), we will only use two different definitions and then elaborate on the concept of Lean Manufacturing.

- *Continuous elimination of all waste resulting in a system of value added activity* (Internet: Best Management Articles).
- *Lean Manufacturing is the art of raising quality, lowering costs, improving delivery, generally becoming competitive by removing waste and concentrating on activities that add value for the customer* (Pullin, 2000:43).

From these definitions and the literature study that was conducted on LM, it was clear that the main objective was to eliminate waste in all processes to improve an organization as a whole. The waste they refer to is not just on the production floor, but in reality it needs to be eliminated throughout the whole organization from finances, Human Resources, Logistics, IT and especially top management.

Another aspect that is clear from LM is that it has a culture. For LM to work, everybody must believe in it and really pursue it from the top down - from management to floor workers. But it doesn't stop their either, because for LM to work you also need to take your suppliers and networks into consideration and make them part of the dream as well. You need to form long term relationships with them to improve factors such as quality. This will be discussed later when we look at just-in-time.

If everybody does not truly believe in LM, and that it will be beneficial to the company but also to them individually, implementing LM will be very difficult and the right results will not be obtained. In fact, even worse results will be obtained because it requires 100% commitment and a passion from everyone involved (Liker,2004:13).

To put more emphasis on the importance of everybody's commitment and involvement to make LM work, we look at: The 4P model (Liker, 2004:13). First of all the model

shows that LM has a culture and a philosophy, and that it needs everybody's participation, as well as continuing to constantly strive to improve in all aspects of the business.

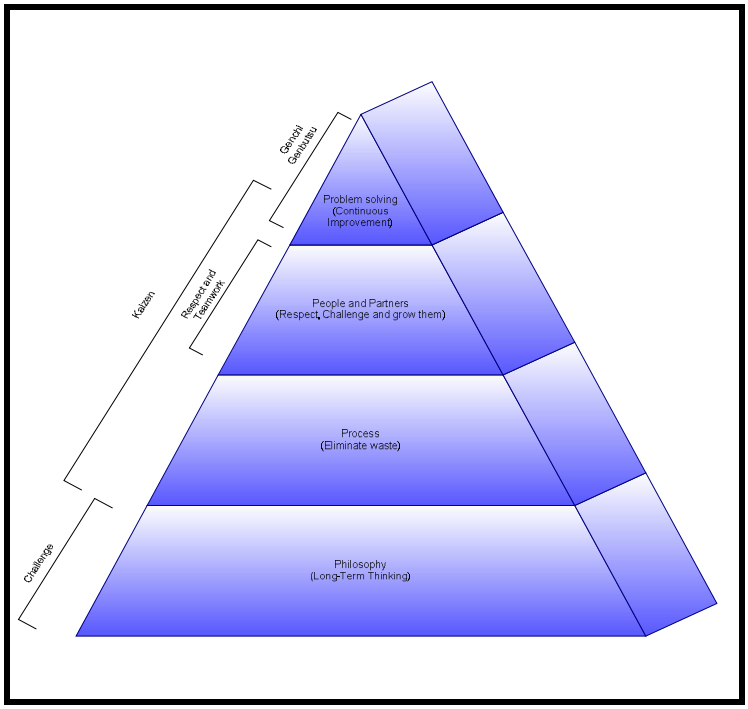


FIGURE 2: THE 4P MODEL

We previously said that LM primarily focuses on eliminating waste. There are currently 8 different types of wastes identified by the pioneers of LM and they are listed below (Liker, 2004: 28-29):

1. Overproduction: *Producing parts or components which there are no customer orders for, which results in unnecessary holding costs, raw materials used, labour costs etc.*

2. Waiting (time on hand): *Workers that are waiting for a machine to perform a task, tools or parts to be issued etc.*

3. Unnecessary transport or conveyance: *Refers to carrying Work-in-Progress (WIP) over long distances, raw materials are located in the wrong areas of a plant and needs to be moved long distances.*

4. Over processing or incorrect processing: *Parts that needs to be reproduced due to wrong tooling equipment, defect parts, producing a wrong product at the wrong time.*

5. Excess inventory: *Excess raw material, WIP or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs.*

6. Unnecessary movement: *Wasted motion where workers have to look for tools or material, searching for lost material as well as materials that are moved from one place to another unnecessary.*

7. Defects: *Production of defective parts or correction. Repair or rework of parts due to redesigns.*

8. Unused employee creativity: *Losing time, employee ideas and creativity by not engaging with your employees.*

To effectively implement LM principles, the main objective is to eliminate as much as possible of the 8 wastes described above. We will later address the wastes that exist at OMC and how it will affect them by eliminating these wastes.

Implementing lean will lead to strategic benefits to an organization. In table 1 (Heumans 2002: 31) it is stipulated how lean principles can lead to strategic benefits, as well as what these benefits are.

TABLE 1: LM IMPLEMENTATION BENEFITS

LEAN IMPROVEMENT	IMMEDIATE RESULT	ORGANIZATIONAL BENEFIT
One-piece flow work cells	Reduced production cycle time	On-time delivery
JIT (Internal supply chains of materials)	Reduced Work-in-progress	Less space required
Kanban systems	Fewer material handling errors	On-time delivery
JIT (external supplier)	Reliable material sourcing	On-time delivery to

		manufacturing
Setup and changeover reduction	Shorter production runs possible	Reduced raw materials quantities
First-time quality	Inspection eliminated	Quality of customers insured
Employee involvement	Improved labour productivity	Improved quality of product

A more detailed discussion of “what” and “where” some of these principles will be applicable to the project at OMC will be discussed later.

PERSONNEL

Personnel and team work is just as important as any of the other aspects discussed previously. In fact, in the end it is the people and workers that add value to your company by actually manufacturing and producing finished products for sales. Laying off of personnel after long production runs or finished projects, contradicts all the characteristics of LM, long term relationships, continuous improvement, etc. If production runs are finished, feedback sessions and redesign and configuration of the processes should be made, these should include the working personnel. They are the ones working with the products and they can give valuable information, ideas and creativity to improve processes. This is the concept in LM which is known as the culture. If you involve them in the process improvement phase, you start by creating a culture that seeks continuous improvement all over your organization.

When line workers start developing and imparting the skills of resolving problems themselves, your organization will successfully become lean, in fact it will be faster than your counter competition. If your organization can successfully implement lean, an increase in market share will be evident because of reduce costs and improved quality and responsiveness.

1.1. JIT

Just-in-Time (JIT) is one of the most important principles of LM and is one of the many techniques a lot of companies strive to apply and achieve.

We first need to start by gathering a clear description and definition of what Just-in-time (JIT) actually is. Everybody seems to know the "buzz word" JIT, but not everybody really understands what it is all about.

"*JIT is the successful completion of a product or service at each stage of production activity from vendor to customer just-in-time for its use and at a minimum cost* (Schniederjans, 1993: 4)".

The main objective and driving force of JIT is to reduce waste by improving the way an organization manages their inventory, and applying JIT management principles. These principles can be summarised as follows (Schniederjans, 1993: 26):

- Cut lot sizes and increase frequency of orders
- Cut buffer inventory
- Cut Purchasing costs
- Improve materials handling
- Reduce inventory levels – seeking a balance between zero inventory and stockouts
- Seek reliable suppliers

1.1.1. REDUCING LOT SIZES

Reducing lot sizes must be to only order what will be used by production at the absolute minimum safety stock needed (Monden, 1986: 121).

The first principle states that lot sizes should be cut, while the majority of the organizations in industry use the popular EOQ model approach. Economic order quantity (EOQ) models are used to determine the quantity or lot size that should be ordered at a time at an optimal cost. The formulas for basic EOQ models will be shown and compared with modified JIT/EOQ models later in this section.

Although it keeps in mind all the costs involved and the carrying costs of raw material it doesn't comply with the JIT principle. For example a firm might order a lot size of 40 units to produce 20 units over a production period of 2 weeks. This means the firm only produce 2 units/day or 10 units/ week. This example of EOQ modelling contradicts the

JIT principle because the firm will have 20 units of raw materials on their premises, which they are not going to use for another week. This increases inventory levels, reduce space capacity and increases work loads of material handlers unnecessarily.

Another big concern with these models is that they are connected to a Master Production Schedule (MPS), the planning production rate over a period of set time. But it does not keep track of the actual progress of the MPS and the production rate. If production falls behind schedule the EOQ lot size will still be ordered regardless of whether the previous ordered raw materials for that job is actually consumed. This creates unwanted excess inventory levels. If production is in front of schedule, material shortages will be experienced.

Using these examples above describes JIT at its best, because it will reduce the inventory levels, increase productivity and reduce lead times needed for materials. This is because materials will only be used when they are needed. This is achieved by applying Kanban systems. Kanban is the soul and driving mechanism for JIT and will be discussed in the next section.

Modifications to the EOQ models were made to make them more applicable for the JIT environment and were labelled - JIT/EOQ models. The formulas for both models are shown and compared below.

1.1.2. **BASIC EOQ MODEL**: (Winston, 2004: 108-110)

$$\text{EOQ ORDER QUANTITY } (Q^0) = \sqrt{\frac{2DO}{C}}$$

$$\text{EOQ TOTAL ANNUAL COST } (T^0) = \frac{CQ^0}{2} + \frac{OD}{Q^0}$$

Where: Q^0 = cost minimizing order quantity in units under EOQ system
O = ordering costs in Rands per order
D = annual demand in units
T^0 = minimized total annual cost in dollars under EOQ system
C = carrying costs in Rands per unit

1.1.3. **JIT/EOQ MODEL**: (Schniederjans, 1993:41-43)

JIT/EOQ ORDER QUANTITY (Q_n) = $\sqrt{n}Q^0$

JIT/EOQ TOTAL ANNUAL COST (T_{jit}) = $\frac{CQ^0}{2n} + \frac{OD}{Q^0} = \frac{1}{\sqrt{n}}(T^0)$

JIT/EOQ DELIVERY QUANTITY (q) = $\frac{Q_n}{n}$

SAVINGS BY SWITCHING TO JIT/EOQ = $\left(1 - \frac{1}{\sqrt{n}}\right)T^0$

Where: Q_n = cost minimizing JIT order quantity in units per each delivery

n = optimal number of deliveries during the year

Q^0= cost minimizing order quantity in units under EOQ system

T^0= minimized total annual cost in Rands under EOQ system

q = optimal number of units per delivery

T_{jit}= minimized total annual cost in Rands under EOQ system

JIT/EOQ OPTIMAL NUMBER OF DELIVERIES (n_a) = $\left(\frac{Q^0}{2a}\right)^2$

Where: n_a = optimal number of deliveries with an "a" targeted level of average on-hand inventory

Q^0= cost minimizing order quantity in units under EOQ system

a = a specific targeted average inventory level in units

1.1.4. GRAPHICAL COMPARISONS: (Schniederjans, 1993:35)

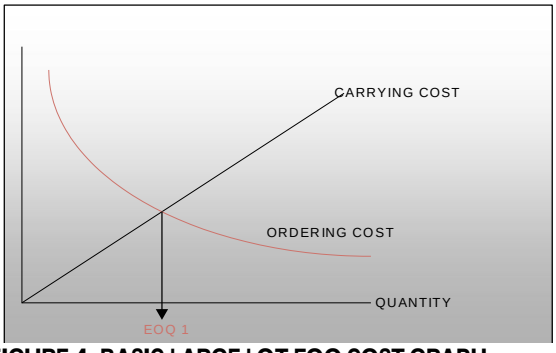


FIGURE 4: BASIC LARGE LOT EOQ COST GRAPH

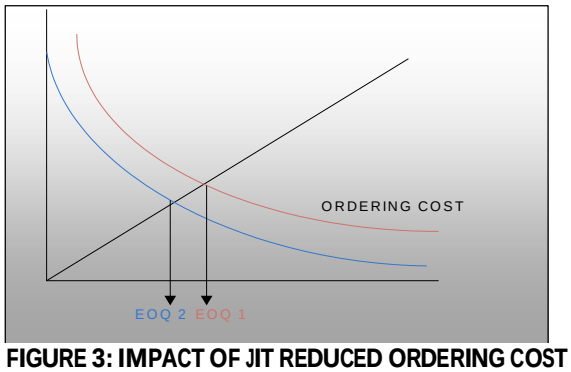


FIGURE 3: IMPACT OF JIT REDUCED ORDERING COST

The previous graphs show how inventory can be reduced using JIT/EOQ models, rather than just a normal large lot EOQ model.

When we compare the two models with each other and with the graphs, it is clear that moving to smaller more frequent lot sizes will reduce the cost of having inventory. Not only will it reduce the cost, but it will also reduce buffer inventory levels, material handlers' workload and it will increase space capacity to the plant. This addresses all of the JIT principles mentioned earlier.

1.1.5. SEEK RELIABLE SUPPLIERS

The last point of the JIT principles, seek reliable suppliers, is one of the most important principles for the implementation and success for JIT systems.

This principle puts emphasis on long term relationships with suppliers. Long term relationships with suppliers will have one of the biggest impacts on the success of any JIT implementation project. This will determine their capability to deliver more frequently, in smaller batches, and on time. It will also ensure that the quality of products complies too the standards and requirements, nearly 100% of the time. This refers to perfect order fulfilment metric in the SCOR methodology. The right product at the right time in the right quantities ordered with zero defects. (SCOR 2008: 2.1.1) Thus JIT is working on a two-way street principle. It must be from your organization as well as from the supplier's side.

To achieve this is not an easy task but is well achievable. This can be achieved by creating and conducting training JIT programmes for all the suppliers by experts in your own company or consultants. The main objective is that they need to understand the reason for change and the benefits and rewards that can be obtained and how it is beneficial for both parties. This can all be planned for and included in the training and briefing sessions with the suppliers.

If successful training is achieved towards your suppliers it will have a chain reaction in the Supply chain network. It is important to know from a Logistical and supply chain view that your suppliers have suppliers and their suppliers have suppliers, so the supply chain does not begin with your suppliers and ends with your customers. It is stretching beyond that. A diagram illustrating this concept is shown below.

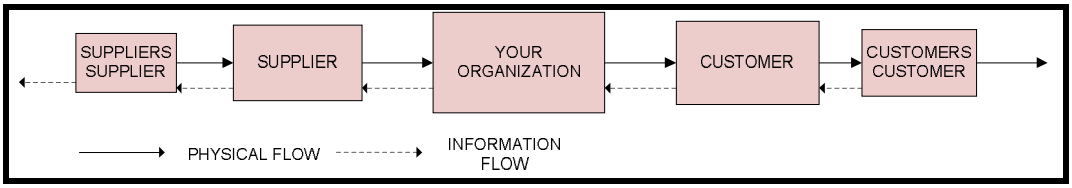


FIGURE 5: SUPPLY CHAIN NETWORK

1.1.6. COMMUNICATION

The success of implementing JIT across the whole chain above lies in the communication between all the suppliers. If there is no communication between the chain of suppliers and customers, the probability of success for the JIT implementation will not be high.

Communication between management and the workers on the floor is also crucial. It might not be verbal communication in the sense of the actual voice of the workers, but it refers to the actual production rate and the use of raw materials. The rate at which materials are used for production is a big factor in a JIT system to ensure that the right quantities are replenished at the right time.

1.1.7. AUTOMATION

One of the rules in a JIT and LM environment is that you only automate where machine can do a better and more accurate job than humans. This normally applies to highly tedious and repetitive work like spot welding in the automotive industry. Do not automate for the sake of automation. Humans have a great sense of freedom over any machine or robot where it can think to resolve an unplanned problem; machines do not have this capability.

1.1.8. 5S

5S basically refers to basic housekeeping rules. The term 5S is simply allocated, because it consists of 5 Japanese words all starting with a S. The 5 words and their basic meaning is described in the table below (Schniederjans, 1993: 4).

TABLE 2: 5S WORDS AND DECSCRIPTIONS

JAPANESE WORD	DESCRIPTION/MEANING
SEIRI	ARRANGEMENT
SEITON	ORDERLINESS
SEISO	CLEANLINESS
SEIKETSU	CLEANUP
SHITSUKE	DISCIPLINE

By applying 5S will mean that every part/tool/equipment will be in its allocated space in an orderly and clean manner. After a shift or specified time and task everything is cleaned and still in their right places. And this needs to be continuously applied with discipline.

5S- will mainly reduce high setup costs and reduce lead times for set up costs to perform tasks. This is achieved by eliminating time operators need to look for tools/material/equipment to perform their tasks by applying the 5S principle.

1.1.9. **MEASURING JIT PRODUCTION MANAGEMENT**: (Schniederjans, 1993:95)

A metric to measure the actual value added to a specific component or product during production can be obtained by the following easy formula:

$$\text{Value added} = \frac{(Rand\ sales) - (materials' purchase\ costs)}{number\ of\ workers}$$

To evaluate the efficiency of workers under a JIT system we can use the following formula:

$$\text{Worker efficiency} = \frac{Standard\ working\ hours\ allowed}{Total\ JIT\ hours\ used}$$

The ratio of this calculation will become greater than 1 if JIT system is successfully implemented and has an impact on the organization.

1.1.10. QUEUES

When materials are managed wrong and excess inventory is experienced in a facility, queues tend to form in various places from stores to the production floor. When queues form the natural tendency of management is to add capacity, when queues are short management tend to reduce capacity. By applying JIT, queues can be reduced and more capacity for production is obtained as well as the work load of material handlers and stores personnel are reduced. Most of the time, 70% - 80% of set up times consists of queues (Monden, 1986: 122).

1.2. KANBAN

KANBAN can be defined as the production scheduling and inventory control card system (Schniederjans, 1993:87).

Kanban is a Japanese word and its meaning literally means card. Thus a Kanban system uses plastic cards to control production scheduling and inventory levels of a production facility.

There are 3 types of cards that can be used (Schniederjans 1993:89):

1. The production authorization card: *This card signals that production of a certain item or procedure can begin.*

2. The vendor authorization card (also known as withdrawal card): *This card signals the vendor/store pickers to send some specific item that is needed on the line or warehouse.*

3. The conveyance authorization card: *This card gives a material handler authority to move a product from one place to another location. This also ensures to comply with 5S and maintain discipline.*

The diagram (Monden, 1986: 131) below illustrates how the kanban system works. A brief description will follow the diagram to make it more clear how the procedure will follow.

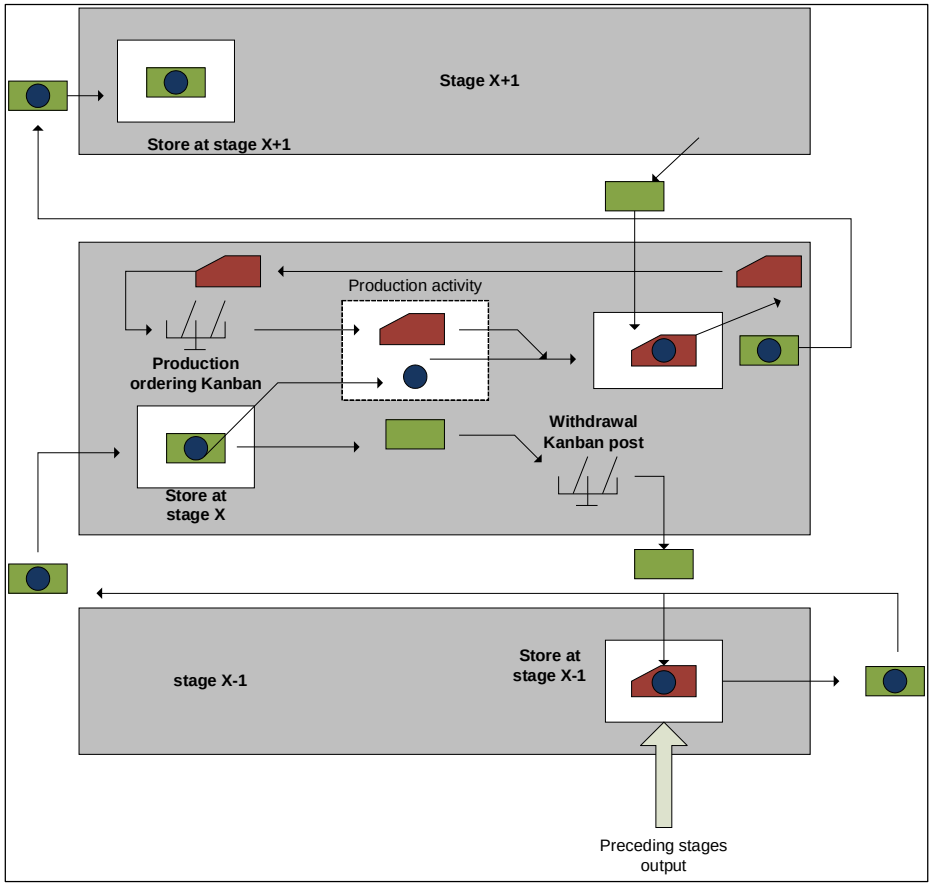


FIGURE 6: KANBAN FLOW FOR DUAL CARDS

A production card is sent to a certain station on the production line from a following station X + 1. This card automatically gives the order and authorization to start production at this stage. The production card is sent with the raw materials and a withdrawal card needed for that job to station X. Production then completes the task and the product is stored with the production card. A withdrawal card/vendor authorization card is placed on the withdrawal kanban post. When the kanban is full at the withdrawal post at station X it takes a withdrawal card to the stores department which orders them to replenish the raw materials at station X. When a withdrawal card is drawn from station X to Station X + 1, the product and the withdrawal card is moved to station X + 1. The production card that was stored with the product is then sent back to the beginning of the production stage at station X, where there is also a kanban production ordering post. These posts act as safety stock levels to ensure the right lead time is allocated to perform the kanban action with the least amount of inventory. This procedure can be

looped as well between the stores department and the suppliers that supply the required part.

This whole procedure is looped to keep inventory levels at a minimum while maintaining enough inventories to meet production demand. This is known as a manual kanban system because the system is driven by physical cards.

eKANBAN

But the system can also be driven by means of technology by sending messages via network servers to the applicable stages and stations. This is also known as Electronic Data Interchange (EDI). Instead of moving physical cards messages are sent in email format to suppliers or stores etc by using a network. This can be managed automatically with barcodes which makes the process so much quicker because the inventory levels are updated virtually in real time, which means that the time it takes to move a kanban card to a next station is eliminated. Thus the diagram will look almost identical, but instead of physical kanban cards the flow will be illustrated with dashed lines indicating the flow of information.

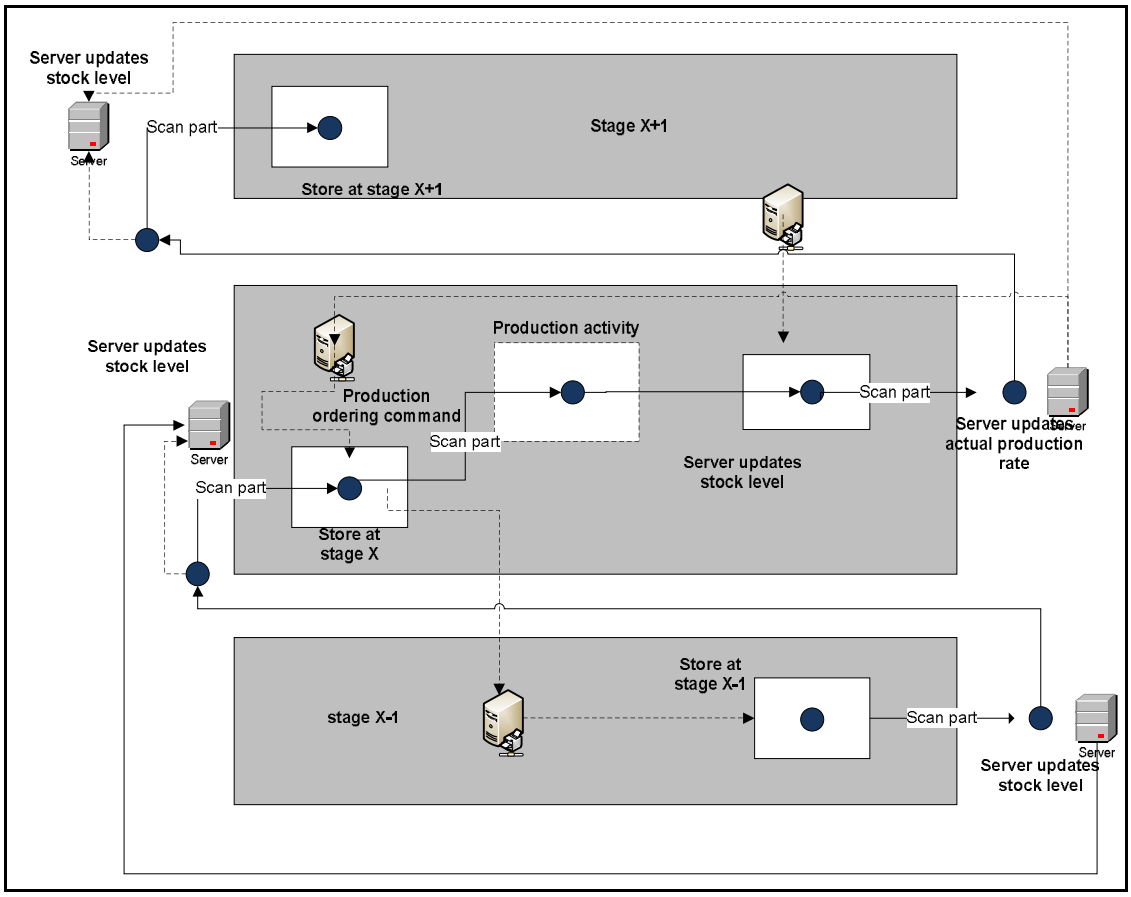


FIGURE 7:EKANBAN DIAGRAM

KANBAN SIZE FORMULAS: (Schniederjans, 1993:90)

Formulas to determine the kanban card sizes for all three types of cards production-, vendor- and conveyance authorization cards are given below.

Amount of ideal production authorization cards:

$$n_p = \frac{(d)(t)(1+e)}{c}$$

Amount of ideal vendor authorization cards:

$$n_v = \frac{(d)(2+t)(1+s)}{D(c)}$$

Where: d = the average daily planned demand
t = the average time for setup used for a unit or lot size
e = value between 0 – 1 that represents the percentage of insufficiency in a plant
c = is the amount or capacity per kanban
s = represents the safety stock level

1.3. INTEGRATION OF JIT/MRP

Before we look at the integration between MRP and JIT we need to define MRP. JIT is already defined and explained.

Material Resource Planning (MRP) uses software to help plan and control the use of dependant demand inventory items and schedule finished product production. (Schniederjans, 1993:166)

What it means from the definition, is that MRP is a program that uses the Master Production Schedule (MPS) to plan the procurement and expediting processes of raw materials needed to complete production according to the MPS. This is also known as a push system in LM because materials are pushed into the process to a planned and anticipated production demand.

The one main concern of MRP programmes is that they do not take into account the actual usage of materials on the production floor because it lacks communication input from production. Normally MRP works well in an environment where Lead-time variability is high.

JIT is an example of a pull system where an organization is building in reaction to a present demand. The actual consumption of raw materials and a true production rate are used as the main drivers for releasing new inventory and raw materials into the facility. It can be on the line or in the warehouse from external suppliers. We know by now, as discussed previously, that JIT uses Kanban systems, which acts as the communication tool of actual material usage and production rates. Normally JIT works well in an environment where Lead-time variability is low.

The main question is: can JIT and MRP be integrated to create a Hybrid model of the two models? According to many literatures the two can be combined. A figure XX (Foo

& Kinney, 1990: 417) is given below to show the integration options between MRP and JIT systems under different lead-time variability.

LEAD-TIME VARIABILITY	MATERIAL PLANNING	CONTROL SHOP ORDER RELEASE	SHOP FLOOR
LOW — **PULL CONTINUOUS FLOW**	JIT	RATE BASED	JIT-PULL
HYBRID PUSH-PULL: BATCH REPETITIVE	JIT-MRP	PULL OR MRP	PULL
HYBRID PUSH-PULL: BATCH DYNAMIC	MRP	MRP	PULL OR ORDER SCHEDULING
HIGH — **PUSH CUSTOMER ENGINEERING**	MRP	ORDER SCHEDULING	OPERATION SCHEDULING

FIGURE 8: TAILORED PRODUCTION CONTROLS

The hybrid model will work where MRP will be the driving force of the planning, what materials needs to procured, where they need to be routed and what the planned and anticipated demand of production will be. JIT will then be the communication tool using a kanban system to actually inform MRP via EDI or manual input, depending on the organizations system, what the actual production rate is. The delivery lot sizes can be manually set before a project starts in MRP as well as the required lead times. If these parameters are set according to a JIT model the MRP can do its scheduling and planning according to these parameters. The only difference now is that using JIT and kanban systems, MRP can be informed what the actual usage is, update the replenishment levels for materials and expedite according to that. In short, this will enable the JIT philosophy; materials will only be ordered and delivered when needed.

This will save companies a lot of unnecessary inventory, increase production capacity and increase accuracy and quality of production.

1.4. CHANGE MANAGEMENT

It is not a secret that people are not eager and enthusiastic to change the way they have worked for many years, to something new and totally different. Thus change management can be one of the biggest objects to overcome when organizations want to implement LM principles and processes.

Thus it is just as important to make them part of the solution and the plan. They must understand the reason behind it and management must clearly portray the benefits to all employees of the company. They need to know and understand that it will make their job more efficient and important. If they realise they have a bigger responsibility to make the company grow they will not be so reluctant to change.

According to Liker (2004: 182): "Y*ou need to grow leaders who thoroughly understand the work, live the philosophy and teach it to others."*

1.5. CURRENT DATA ANALASYS:

OMC is currently busy with designing a new ERP solution for their business. All the current processes were mapped in IDEF format. Their improvements and to-be requirements were also mapped out. The following findings came out of those sessions, where all the involved key role players defined the current business processes.

- A lot of materials received gets lost and misplaced because of insufficient management processes. Because OMC expanded rapidly over the past 3 years their current processes can no longer cope with the product demand.
- Because of misplaced materials and insufficient materials handling processes, a lot of raw material needs to be reordered.
- Visibility of raw materials is not well controlled if controlled at all.
- Production productivity is only at about 60% because of wasted time spent by workers looking for lost material, material shortages and defective parts.
- Large queues tend to form at the Goods receiving department because of big lot sizes that gets ordered.

- Because of poor inventory management and communication, the result is excess WIP inventory on the production line.

OMC is wasting a lot of cash and worker hours because of these processes. For example, there are on average 300 line workers for a project. They cost OMC on average R58.00/hour and they only work productively 60% of their time. A project is on average over a length of 5 months and consists of a customer demand of 150 vehicles. Workers get paid for 8.5 hours a day. Taking this into consideration OMC is wasting R5, 916,000.00 worth of labour hours costs plus an additional average of R5, 000,000.00 for obsolescence stock per project.

This is a total labour hours wasted of R10, 916, 000.00

This is without taking into account the holding cost of excess inventory not used on time.

A table in appendix B shows the inventory stock levels of big parts and components. These are all supplied locally, and still they manage to experience either excess inventory or material shortages.

It is clear that OMC needs to improve their current business processes and that it needs to be addressed.

1.6. CONCEPTUAL DESIGNS AND POSSIBLE SOLLUTIONS

Because OMC is designing a new ERP system and already purchased a barcode software module at an additional cost, it will make sense to pursue a barcode solution.

By implementing an integrated barcode solution with the new ERP system they will:

1. Obtain better control of their materials by applying 5S and accurate routings
2. Increase their picking accuracy,
3. Reduce queue times at various departments.
4. Increase the visibility of materials in the plant.
5. Achieve more accurate stock levels.

6. Accurate space allocations of parts.

Because of the new ERP solution that is being designed, the barcode system can be utilized more by using it as an input measure of actual stock levels in the warehouse, production line and parts that needs to be painted and then sent to the desired location/workstation. By implementing this strategy it will act as an eKanban system that will in turn, also be the first phase of moving towards a JIT system.

With a modification to the current part number format, a more accurate routing system can also be achieved by sending the materials to the desired location the first time round. Sometimes parts get booked in at Goods receiving, then get booked into stores, and then sent to the line, sent from the line to the paint shop and only then returned to the same location on the production line where the part is assembled to the vehicle.

This process can be improved by implementing a new part numbering method for more advanced routing of parts.

The current part number only reveals a parts identity but not its location or routing. Creating a new part number can resolve this problem.

A figure below shows the conceptual design framework of how the barcode, ERP and MRP will be integrated. An additional figure is also shown in appendix B.

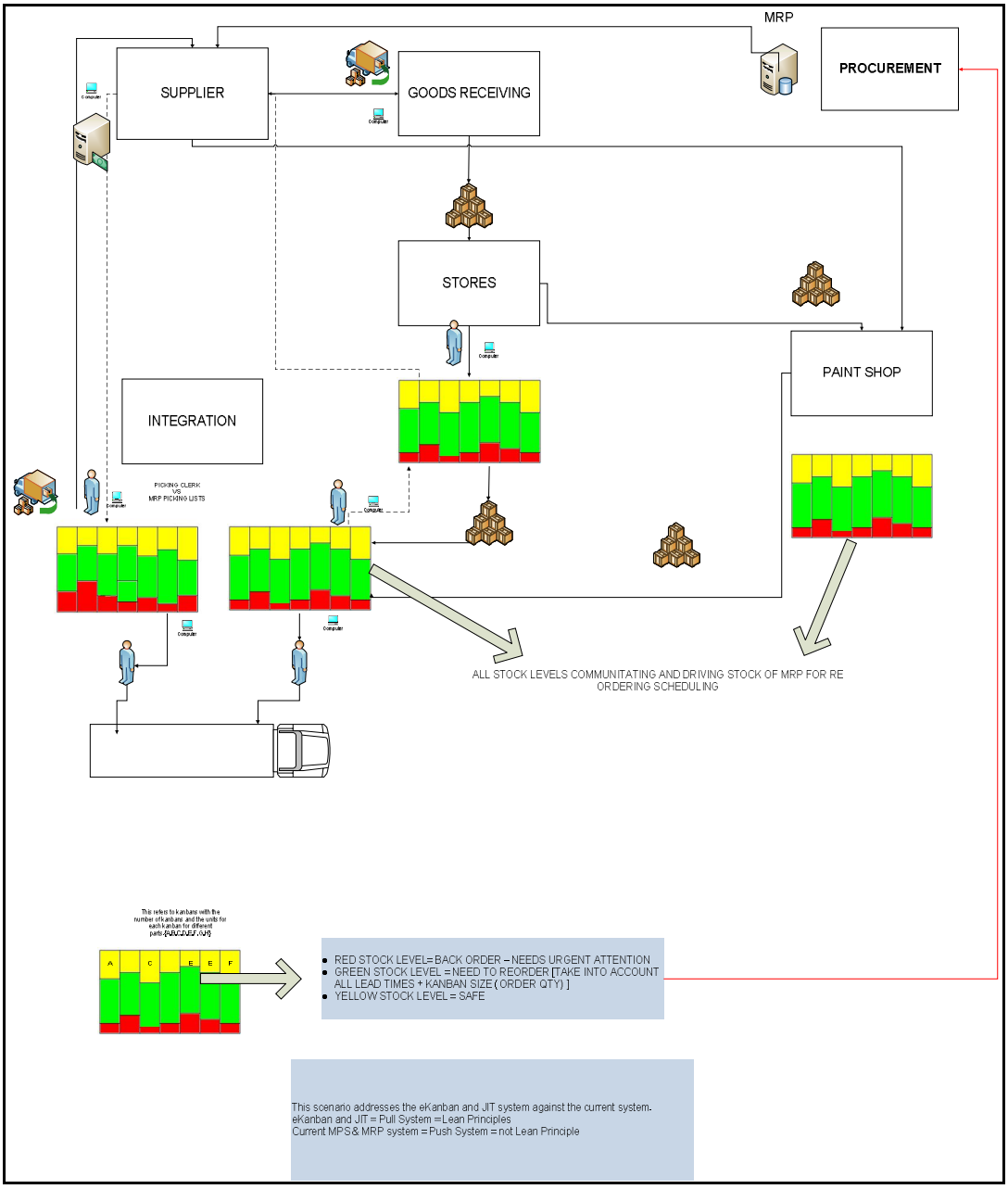


FIGURE 9: CONCEPTUAL DESIGN A

CHAPTER 2: IMPLEMENTATION

WORK APPROACH

The approach will be based upon the topics and techniques discussed earlier, and are broken down into the following phases and steps.

Table 3: IMPLEMENTATION PLAN

PHASES	DESCRIPTION OF TASK
Phase 1	Analyze Processes
a	Gather Organigrams
b	Define current business procedures(end-to-end)
c	Map processes against organigrams(who is responsible for what process)
d	Evaluate against generic best practices (bar code implementation guide)
e	Define manual process for kanban
f	Define to-be processes (complying with bar code)
g	Define bar code application process options (outsource, internal, suppliers)
Phase 2	Station layout
a	Define generic station layout procedure
b	Structure drawings
c	Linking parent-to-child drawings on BOM
d	Group above together
e	Determine qty level on floor
f	Determine replenishment schedule
g	Design station layout
h	Implement procedure to few stations (closing loop from production - procurement)
i	Evaluate efficiency of station layout(stock levels, movements)
j	Co-operate to-be state for bar coding procedure
Phase 3	Generate product families
a	Group bar coding types together (electric, metal plates, rubbers etc.)
b	Define different labelling options
c	Assign labelling method to part/s
d	Test labels assigned to product families
e	Define different Labels to be used (pdf417, code 39, code 128 etc)

Phase 4	Equipment required
a	Gather all specifications and design requirements from vendors (ERP, Bridgelogix)
b	Gather information of complying scanners
c	Locate suppliers and gather quotes
d	Decision analysis of scanners (BAN - tables and probabilities
e	Allocate scanners to product families
f	Design station layouts and scanner requirements against parts locations
g	Determine qty of each type of scanner requirements
Phase 5	Cost analysis
a	Current costs without bar coding (lost costs- obsolescence, lost time, paper work etc.)
b	Determine costs of all different labels
c	Determine total cost of labels applied to complete project
d	Determine improved productivity savings
f	Cost of marking station layout markings , 5S-labels
g	Cost of kanban cards
h	Cost of scanners
i	Cost of wireless network
j	Cost of Bridgelogix (software interface between scanners and ERP)
k	Calculate value of implementing bar codes
Phase 6	Evaluation and feasibility study of project
	Total Cost of implementation
	Projected savings per project (productivity , obsolescence stock)
	Determine break-even point
	Determine ROI?
Phase 7	Conclusion
Phase 8	Future improvements and implementation plans
	Long term supplier relation ships
	Moving towards JIT environment
	Internal consulting at local suppliers
Phase 9	Final Document completion

PHASE 1: DEFINE AND ANALYZE PROCESSES

The company's organizational charts were obtained which was followed by workshops to identify all the role players who were involved in the processes. After all the role players were identified and assigned to all the operations and processes OMC follows, process flow charts was drawn up from the functional diagrams. The focus is on the materials management and production processes because this is where the most value will be added by implementing LM principles and is also the focus point for the bar coding system. These AS-IS processes include goods receiving, binning and picking procedures and is given in appendix C. All the information flow between all the role players, procurement, material planners and suppliers, were taken into account.

After these processes were analyzed, we focused on the requirements for OMC to improve their current processes as well as integrating the LM principles and the bar code system requirements. These processes were also measured against reference models that are used in industry. The main objectives of these requirements can be summarized in the following categories stipulated below:

- IMPROVED TRACK AND TRACEABILITY SOLUTION FOR MATERIALS
- REDUCED INVENTORY LEVELS ON SITE - A PULL SYSTEM
- IMPROVED PROCESSES TO CONTROL PRODUCTION
- IMPLEMENT MANUAL KANBAN PROCESS
- DEVELOP REQUIREMENTS FOR A BAR CODE SOLUTION

It was also identified that a need for another department exists. This department will focus on the station layouts, planning of materials replenishment schedules and the necessary lot sizes on the production line. This will be explained in more detail in the station layout phase.

A manual kanban process was developed and implemented. A diagram below explains the basic principle of the kanban while a brief explanation follows after the diagram.

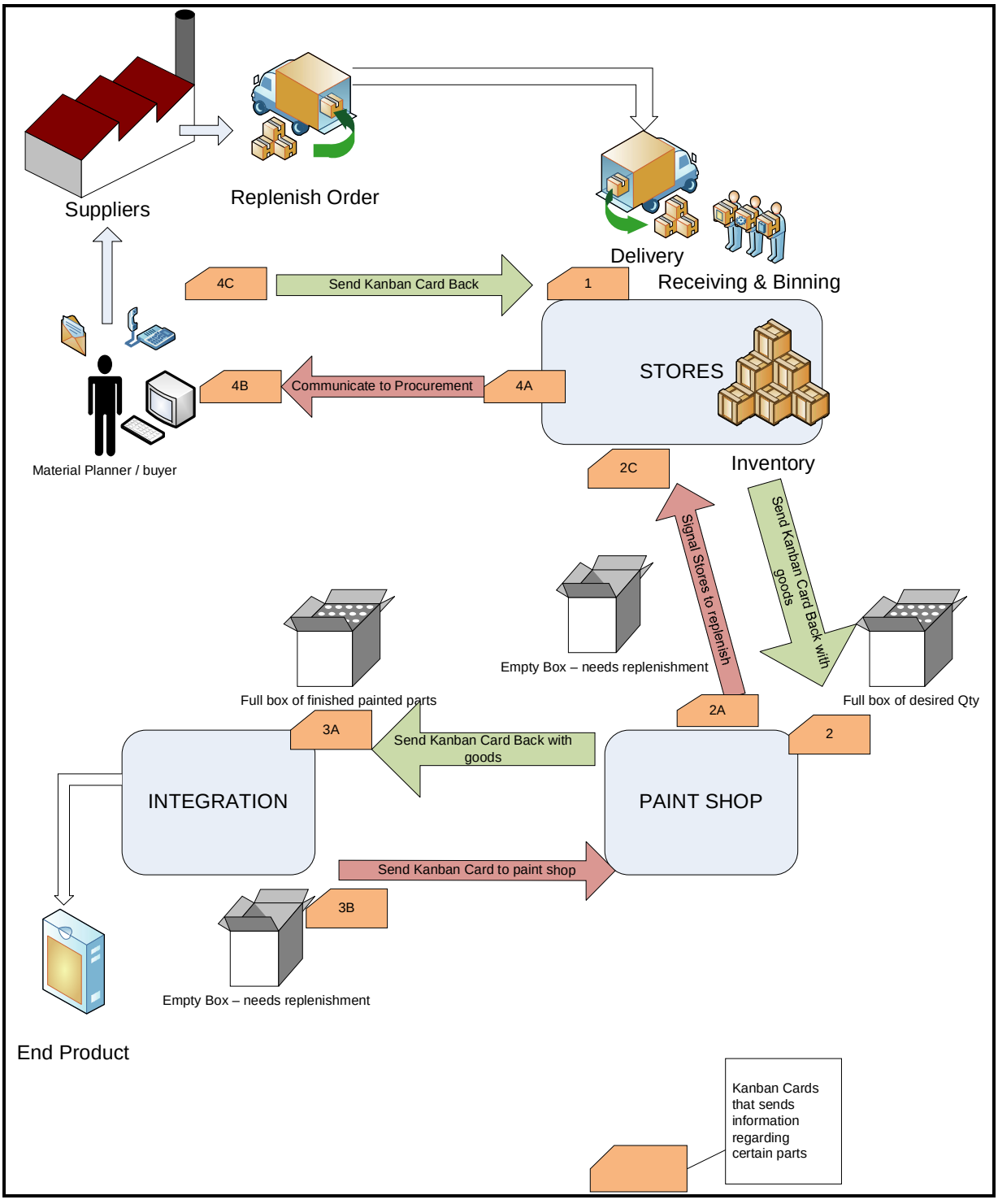


Figure 10: MANUAL KANBAN PPROCESS ILLUSTRATION

From the start of a project all the components' kanban cards are developed with all the delivery addresses and replenishment quantities. The diagram only illustrates the concept, because parts can move in various combinations between multiple internal destinations. A part is sent from the warehouse to the desired delivery for example the paint shop. All those parts go through the painting process. When the integration line reaches a predetermined stock level they will trigger the paint shop to release certain parts on request with a kanban card. The same applies to the paint shop, when they reach their minimum stock levels a kanban card will then be sent to the warehouse to replenish the paint shop stock levels. The warehouse works on the exact same principle except the kanban card is sent to the procurement department where the materials planner and buyer communicate with the supplier via telephone or email to fill the order. Parts are delivered to the warehouse and the parts are united with their original kanban card. This process is looped throughout all the operations and different sections of the production floor.

Since the manual kanban was implemented, stock levels on the integration line were dramatically reduced and the visibility of material increased. A short summary are given in the table below of how the stock levels changed where the kanban process was implemented.

Table 4: INVENTORY LEVELS IMPROVEMENT WITH KANBAN

Operation	Stock level without Kanban (units)	Stock Level with Kanban (units)	% Floor area saved
21	2860	858	70.00%
50	8370	2511	70.00%
60	4260	1704	60.00%
70	8932	3126.2	65.00%
90	40733	8855	78.26%

While the manual kanban process is in a roll out phase the future bar code requirements are developed and documented. These TO-BE flow process charts is shown in appendix D.

IDEF0 (functional diagrams) and IDEF1X (data models) were formulated and forwarded to the ERP software vendor to analyze and verify. The high level of these models is

shown below while the rest of the models are in appendix E. After the feedback from the ERP vendor the next phase of defining the requirements will commence and all processes and requirements need to be revised and updated.

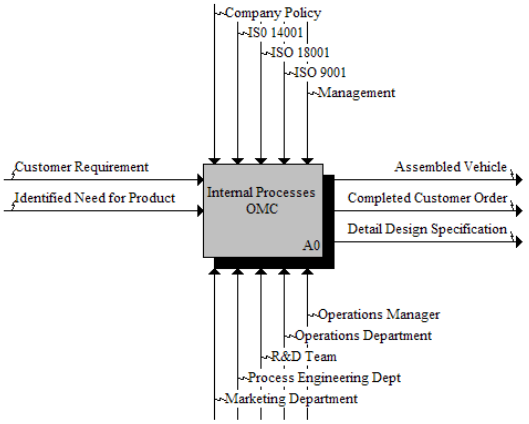


Figure 11: FUNCTIONAL MODEL PARENT DIAGRAM

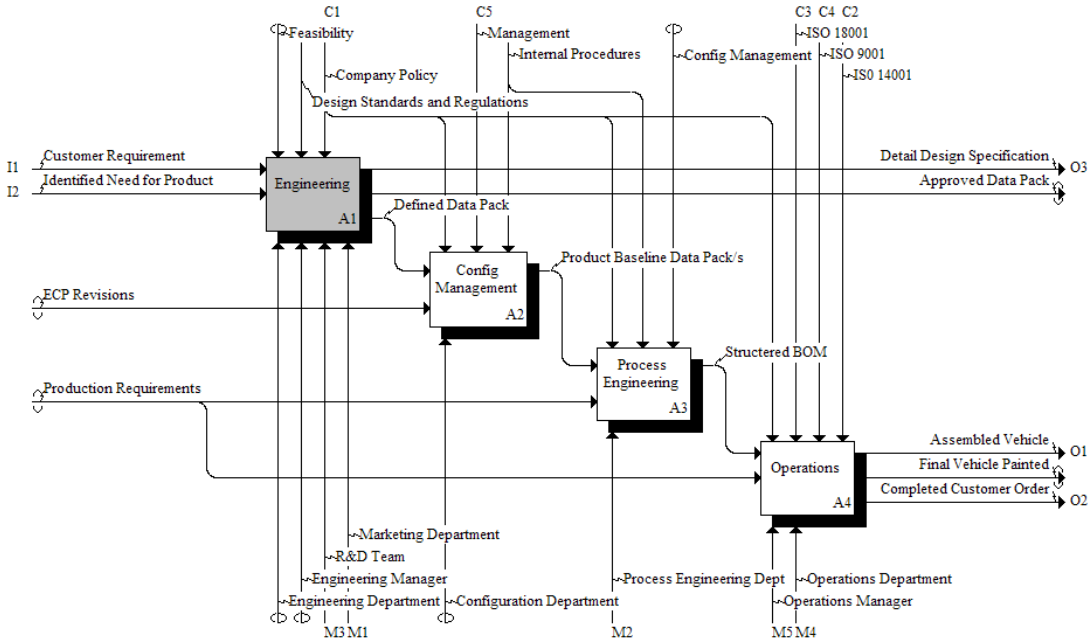


Figure 12: FUNCTIONAL MODEL CHILD DIAGRAM

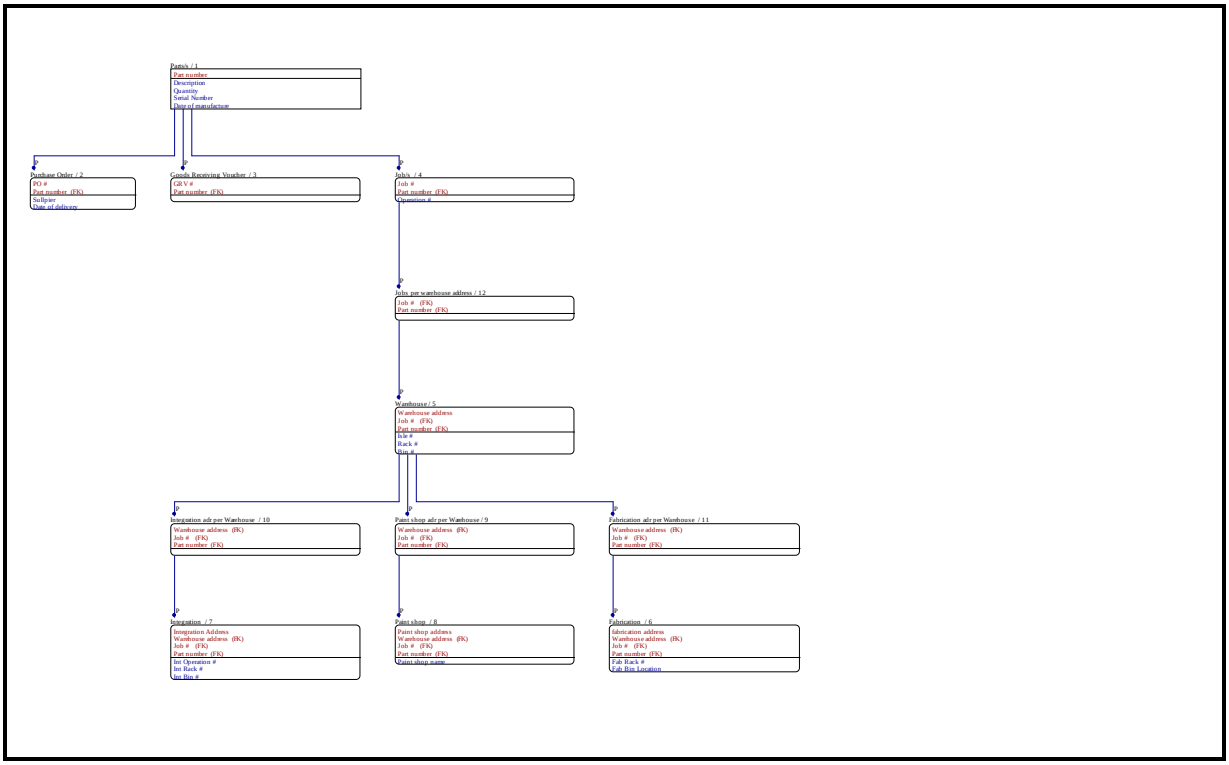


Figure 13: DATA MODEL

PHASE 2: STATION LAYOUT

After analyzing the current processes it was apparent that there is a definitive need for a dedicated department to manage the station layouts and planning. In the past OMC's production demand was not as high and it was not really required. But as the demand increased it is clear that this is a necessary step and will help to control, maintain and compliment production.

The required tasks identified will be as follows:

1. Gather the BOM from process engineering that is structured against parent and child drawings per operation.

2. Determine the space needed for the parts per station.

3. Determine the qty per part that needs to be in a kanban(linbin).

4. Calculate the required amount of linbins, rack space and the type of linbins that will be required.

5. Design the station layout. Every part must be assigned a dedicated location (delivery address) and these locations must be marked precisely. In the future this will be bar coded when the bar code system will be implemented and active.

6. When the station layout is done it is very important that critical parts are in different color linbins and that bolts and nuts should be separated. Another aspect is to ensure that every part linked to a parent drawing should be grouped together as far possible. Currently this is not done, every part in an operation is only categorized according to that operation and no more detail is assigned to those parts.

7. All sub assemblies need to be identified in every operation and routed to the sub assembly area. All the parts still need to have a dedicated location as with the integration line. After the sub assemblies are assembled they will be sent to the integration line as a completed assembled item.

8. Station layouts need to be duplicated in the marshalling/kitting area for the kanban system. These marshalling areas will be formed in the warehouse.

9. Kanban cards need to be made for all the parts and the right quantity of cards need to be calculated to ensure a functional kanban system.

10. Accurate routings should be in place for the kanban system

    Examples of these procedures follow:

- STRUCTURED BOM:

  All the child parts are linked to the parent drawing and are given more depth in terms of its operation number.

  All the parts on the BOM get assigned an operation number, which means that all the parts that will be used in a specific station on the production line. In such operation there is more than one job per station. These jobs need to be broken down into another step to group these parts more accurately. Instead of getting the routing of operation 100 only, it can be expanded into more detail for example operation 100A, 100B, 100C etc. If this procedure is followed on the BOM, station layouts can be designed accordingly as well as more accurate part routings. Because the BOM was unstructured before this step, a macro will be developed that will automatically group and structure the BOM as explained. An example of such a BOM follows below.

Table 5: STRUCTURED BOM TEMPLATE

BOM *WORKSTATION 1: OPERATION 100 - SUSPENSION*						
OPERATION 100 A						
RESOURCE	NAME/DESCRIPTION	QTY	UM	Parent Article	QTY	Storage type
VEH TRANSFER BOX ASSY:						
R0101538	TRANSFER BOX RTC 25	1	EA	R0098114	3	Deck 1
R0102859	BRACKET T/CASE LEFT W/ASS	1	EA	R0098114	3	Deck 4
R0102866	BRACKET T/CASE RIGHT W/AS	1	EA	R0098114	3	Deck 4
R0053967	MOUNTING BRACKET TRANSFER CASE	4	EA	R0098114	12	Deck 4
R2003046	WASHER FLAT NORMAL DIA M16	8	EA	R0098114	24	Small Tray
OPERATION 100 B						
VEH FRONT SUSPENSION						
R2003045	WASHER FLAT NORMAL DIA M12	16	EA	R0098119	48	Small Tray
R2002696	SCREW HEX HEAD (FORGED) M12 X 25	16	EA	R0098119	48	Small Tray
R0104854	RH FRONT SPRINGLEAF	1	EA	R0098119	3	Deck 4
R2003056	LH FRONT SPRINGLEAF	4	EA	R0098119	12	Small Tray
R2002705	SCREW HEX HEAD (FORGED) M16 X 25	4	EA	R0098119	12	Small Tray
OPERATION 100 C						
VEH STEERING BOX						
R0934473	FLAT WASHER BODY SPECIAL	4	EA	R0098115	12	Small Tray
R9202893	NUT NYLOCK M8	4	EA	R0098115	12	Small Tray
R0095994	COOLER OIL TRANSFER BOX	1	EA	R0098115	3	Pallet
R0101538	STGEERING BOX ASSY	1	EA	R0098115	3	Pallet

The whole BOM will be structured according to this format. Some fields are hidden in the spreadsheet for space purposes. In the BOM template above the unit dimensions are also included and the space requirements and amount of linbins and racks are also determined. Before we set up this type of BOM structure every part was in random order, meaning that child parts was not linked to parent drawings and everything was just mixed at each station. This is also a big reason why parts are misplaced and lost while productivity is also not optimal.

From this template we can also use the quantity of each part to determine the quantity of bar codes that we will use as well as assign each part to a specific type of bar code label. After the BOM has been structured and the space requirements determined the station layout can proceed.

- CALCULATION OF THE QUANTITY OF LINBINS REQUIRED:

There are currently 6 types of linbins used at OMC and are classified in Type A to Type F. These classes are grouped according to their respective sizes. We also calculated how many of these bins will fit onto the storing racks they currently use. This will make the designing and planning of stations more efficient.

An example of how this is calculated is shown in the table below:

Table 6: AVAILABLE BINS AND SIZES

	LINBIN QUANTITIES							
	Length (mm)	Depth (mm)	Height (mm)	Volume (m³)	Notes		Quantity	Description
Type A	430	370	175	0.028	White Large		10	Large Tray
Type B	200	370	180	0.013	Black Medium		40	Medium Tray
Type C	185	400	75	0.006	Blue Medium		130	Medium Tray
Type D	90	500	75	0.003	Blue Small		164	Small Tray
Type E	140	270	130	0.005	Grey Small			Small Tray
Type F	140	380	170	0.009	Grey Large with Dividers		50	Small Tray

Racking Dimensions	
Length	2520
Depth	720
Height	450
Levels	4

Small Tray	Medium Tray	Large Tray
28	13.6	5.9
18	12.6	

- STATION LAYOUT:

A detailed plan will be drawn up for each station to assign locations and dedicated delivery addresses to all parts. The layout will also be focused on efficiency and productivity so that production workers do not waste time by looking for material or walking unnecessarily to fetch the required material. The station layouts will focus on a one-step-flow principle, which means workers, should not walk more than one step to obtain their required material, parts and equipment. The layouts will also be focused on efficient material flow designs for an optimized material handling design.

An example of a station layout will typically look like the following diagram. Assigning dedicated parts in this layout will then follow. The racks, work benches, and stilleges are designed in a sense that they all have a dedicated function in the station regarding parts and material flow patterns.

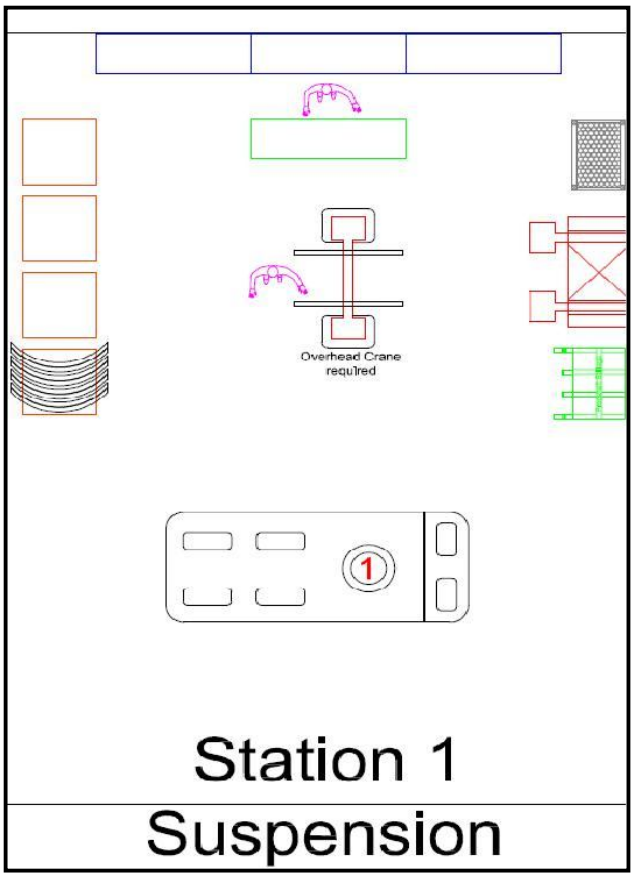


Figure 14: STATION LAYOUT TEMPLATE

The procedures described above will then be followed until all the stations have been designed as well as the quantities on each station and duplicated in the marshalling area.

PHASE 3: CREATE PRODUCT FAMILIES AND ASSIGN LABELLING METHOD

Using the existing BOM's all the parts will be grouped in product families. These product families will be categorized in the following groups. If a certain labeling method will comply with all the parts in a specific group the better. If a part in a group does not fit the specified labelling method it needs to be identified and a special labeling method needs to be assigned to that part. Because there is so many parts the chances of this occurring is not avoidable, but if it can be minimized the better and more cost effective it will be.

The main product families were categorized as follow:

- Electrical harnesses
- Sheet metal and armoured plates
- Axles
- Shafts
- Wheels and rubber parts
- Metal parts that needs to be painted
- Nuts and Bolts
- Pneumatic Parts
- Plastic Pipes (Polymer pipes)
- Steel Cables

All the parts on the BOM need to be placed in one of these categories and depending on the specific property and physical appearance of that part a suitable label will be assigned to that part.

After the labelling methods are assigned to the different products, a sample size of all the product categories will be tested and evaluated. After these tests, final decisions and assignments will be made to all the product types.

2D Data Matrix bar codes were chosen as the bar code type that will be implemented at OMC. The decision was based on the fact that 2D data matrix codes provide the variety and flexibility of the amount of characters that can be used. Another big advantage is that it is available in a wide variety of different sizes that can be used on parts depending on the physical size of a part. Another factor why OMC chose 2D Data

Matrix codes was the fact that industry are moving away from 1D and normal 2D codes to 2D Data Matrix codes.

The field requirements for OMC on the bar codes are listed below:

- Internal Part number
- Serial Number
- Purchase Order Number
- Job number
- Delivery address
- Date manufactured

PHASE 4: EVALUATE EQUIPMENT

The requirements from the ERP vendor, wireless network and OMC's IT department regarding the scanner specifications are shown in the table below. The different types of scanner available in the market are also shown in the table.

Table 7: SCANNER REQUIREMENTS

SCANNERS REQUIREMENTS MATRIX									
Various Requirements from, ERP vendor, Wireless network and OMC IT department		***Scanners available in market***							
#	**Requirements for scanners**	INTERMEC CK30	INTERMEC CK31	INTERMEC CK3	DS3407	DS3478	MT2090	MC3090	INTERMEC 327
1	Able to assign a fixed IP address	●	●	●	●	●	●	●	●
2	*Display 16 lines(down) 20 characters (across)	●	●	●	●	●	●	●	●
3	*To have function keys available	●	●	●			●	●	●
4	Read linear 1D bar codes	●	●	●	●	●	●	●	●
5	Read 2D bar codes	●	●	●	●	●	●	●	●
6	Read machined bar codes like 2D dot peen codes(DPM)				●	●	●	●	
7	Must be able to receive information from ERP server	●	●	●	●	●	●	●	●
8	Must be durable for industry environment		●	●	●	●	●	●	●
9									

**** Represents requirements only for scanners used in the warehouse areas. Requirements without the * is applicable to the integration, fabrication and PUD areas.***

As seen from the table above the Intermec scanners are not DPM readable and only the Motorola models can be used.

After the design of the system, scanners were allocated to the areas where they will be used and the required quantities were also determined for each area.

From the process diagrams and suggested system design the following gates were identified where scanning will take place as well as how many people are needed to perform these tasks. A summary of these gates and quantities are given in the table below:

Table 8: GATES AND QUANTITY SCANNERS REQUIRED

GATE	QTY	TYPE OF SCANNER
Goods Receiving	3-6	MT2090
Quality Assurance	5	DS3407
Binning	6-8	MT2090
Picking	6-16	MC3090
Delivery at Integration	26	DS3478
Delivery at Paint shop	3	DS3478
Delivery at PUD	2	DS3478
Delivery at Fabrication	3	DS3478

Most of the parts will be marked and labelled already from the suppliers. The parts that are not marked or labelled will require internal marking methods. Currently OMC do have printers and software capable of printing labels for parts and a Telesis laser to mark UID plates for all warranty and serialised items. But OMC will also require a pin stamper for additional Dot Peen Marking on some of the armoured metal plates and parts. The model that suite this requirement is the Telesis Benchmark 460 Fully Portable model and is also included in the table below.

The prices for all the scanners and part marking equipment chosen are shown in the following table as well as the quantities of each scanner that will be required.

Table 9: TOTAL COST OF BAR CODING EQUIPMENT AND HARDWARE

	Price	*Qty*	*Total*
DS3407	R11455.92	5	R 57,279.60
DS3478	R14382.83	34	R 489,016.22
MT2090	R19275.75	14	R 269,860.50
MC3090	R24679.87	16	R 394,877.92
BM 460 FP	R88 000.00	1	R88 000.00
		Total	***R 1,211,034.24***

PHASE 5: COST ANALYSIS

Cost of waist during previous projects:

During the past 2 years OMC produced 540 vehicles over 3 projects with a few smaller projects running parallel to these big projects. On these 540 vehicles the amount of production hours lost and obsolescence stock is summarised in the table below:

Table 10: PRODUCTION HOURS LOST AND OBSELESCENCE STOCK VALUES

Project #	Production Hours Lost	Production Hours value @ average of R300/ hour	Obsolescence Stock value in (R)
Project 1	9, 364	R2, 809, 200.00	R19, 820, 937
Project 2	41, 785	R12, 535, 500	R8, 065, 555
Project 3	14, 414	R4, 324, 400	R6, 540, 981
TOTAL:	**65, 563**	**R19, 668, 900**	**R34, 427, 473**

Bar codes and labels:

Letters have been sent out to all OMC's suppliers on a request to supply OMC parts already bar coded. Most of the suppliers confirmed that they will be able to supply OMC with marked products. Only a small amount of parts need to be marked internally by OMC. The direct part marking Telesis machine and all the labels required to mark parts internally is already included in the cost of equipment.

Cost of kanban cards:

Typically a vehicle is assembled out of ±3500 parts and each part requires 6 kanban cards. This means that on average every project must acquire 21000 different kanban cards at an estimated cost of R1.79/ card. Total cost of using kanban cards will amount to ±**R37, 590.00** per project.

Cost of scanners:
From the previous table the total cost of the scanners will amount to: ***R1, 211,034.24***.

Cost of wireless network:
Already developed with ERP

Cost of bridgelogix *(interface program between ERP and scanners):*
Already included in ERP price

Value of implementing bar code solution and LM principles:

The bar coding solution will be the first phase of moving towards a LM environment and will typically reduce queue lengths, improve productivity, material visibility and traceability. Normally a 15% – 30% improvement on productivity can be expected. The second phase of the project is to use all the data available from the system to start implementing pull principles, fine tuning the eKanban system. This will mean that an accurate database should have been developed and in place. Some of the key data will be to capture supplier lead time, waiting time, queue times as well as production time. From this data OMC will be able to calculate accurate holding costs, waiting cost as well as the impact of JIT versus their current methods.

Finally the third phase of the project will be to move to a JIT environment and continually improving all the processes using the data from phase 2.

Currently OMC is working on 65% productivity and on average 2% of all the material purchased becomes obsolete because of material misplacement and engineering changes. A lot of material is ordered in large batch sizes when an engineering change takes place, leaving all the ordered materials ordered on the previous order as obsolete.

A summary of the projected improvement percentages and savings are summarised in the table below.

Table 11: SIMULATED AND PROJECTED SAVINGS PER PHASE

Phase	Percentage improvement between	*Avg Productivity Hours Saved per Vehicle in R value*	*Avg Obsolescence stock Saved per Vehicle in R value*	*Total Rands Saved per vehicle*	*Total Rands saved per year based on 200 vehicles produced*
1	15% - 30%	R 7,348.76	R 13,909.06	R 21,257.81	***R 4,251,562.82***
2	30% - 60%	R 14,605.64	R 29,543.19	R 44,148.82	***R 8,829,764.56***
3	65% - 85%	R 25,074.93	R 47,243.35	R 72,318.29	***R 14,463,657.12***

Note that the following savings are only for improved productivity and reduced levels of obsolescence stock. When OMC succeed to implement JIT and LM principles more savings will occur because holding cost and material handling costs will decrease while capacity to produce more vehicles in a time period will increase.

PHASE 6: EVALUATION AND FEASIBILITY STUDY OF PROJECT

Total Cost of implementation:

The total cost of the project implementation is summarised in the table below:

Table 12: TOTAL PROJECT IMPLEMENTATION COST

Equipment	Cost
Scanners and Marking Lasers	R 1,211,034.24
Bridgelogix	N/A
Wireless Network	N/A
Total Costs	***R 1,211,034.24***

Determine break-even point:

From all the current tenders OMC is busy with it is expected that OMC will get orders for approximately 200 vehicles per year for the next 3 years. An anticipated schedule for 2010 was constructed as well as the accumulated expected savings for each vehicle which was built in a Monte Carlo Simulation to simulate the event of uncertainties.

The total cost of the first year of the project can be formulated as follows:

First year costs = Total Equipment costs + 2X kanban card costs
First year costs = R1, 211, 034.24 + 2 X (R37, 590.00)
First year costs = R1, 286, 214.24

The maintenance costs of the equipment are omitted because all the products come with a full 3 year warranty and maintenance plan.

From the data of the Monte Carlo Simulation in Appendix F a graph was drawn up to show when OMC can expect to break even on the costs of all the equipment purchased.

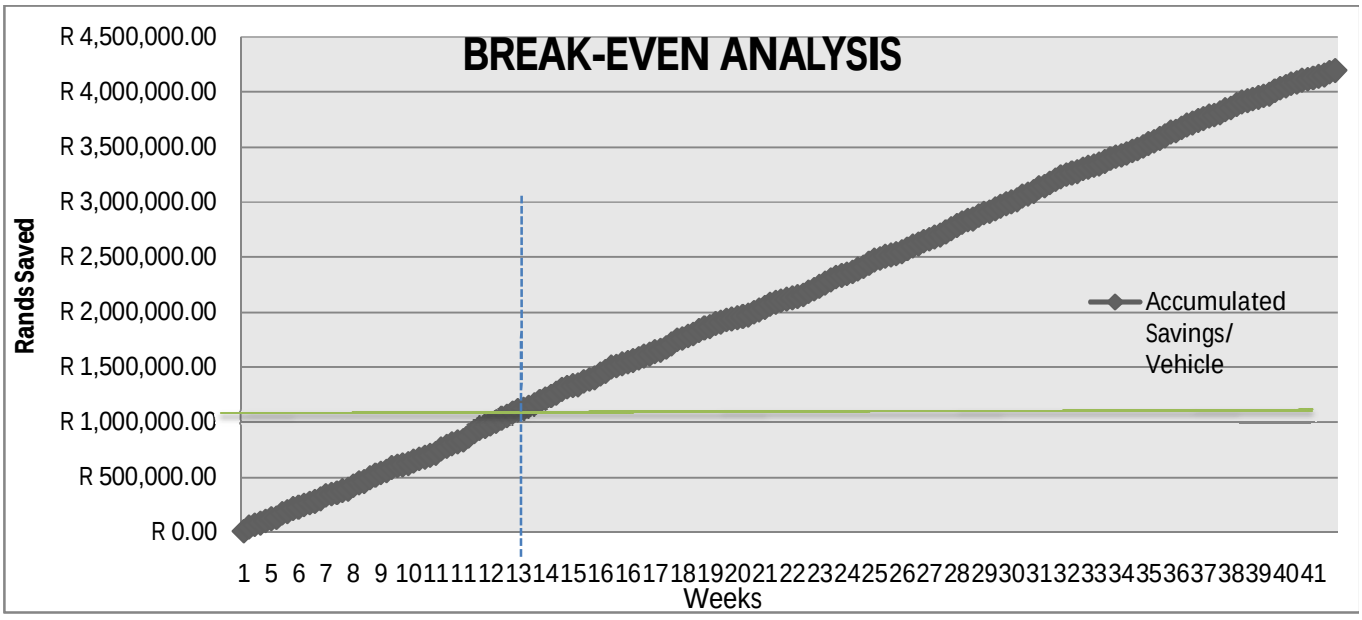


Figure 15: BREAK-EVEN ANALYSIS GRAPH

Determine Pay of period:

From the graph and the Monte Carlo Simulation it is observed that OMC will pay off all the equipment around week 14. From about week 14-16 OMC will start earning on their investment.

Return-on-Investment: ROI

The Monte Carlo Simulation models were used to determine the average savings that OMC can expect over the 3 years to follow. The table below shows the summary of savings for each year.

Table 13: TOTAL PROJECTED SAVINGS

Year	Savings Expected
1	R 4,251,562.82
2	R 8,829,764.56
3	R 14,463,657.12
Total	***R 27,544,984.50***

Thus the ROI can be calculated as follow:

$$\boldsymbol{ROI} = \frac{Total\ earnings}{Cost\ of\ Project}$$

$$\boldsymbol{ROI} = \frac{27,544,984.50}{\mathrm{R}1,286,214.24}$$

$$\boldsymbol{ROI} = \mathbf{21.41\%}$$

The anticipated ROI percentage of 21.41% makes the project of implementing a bar code solution very promising. Any percentage above 4.67% achieved from the simulated data will return a positive ROI percentage. This means that if OMC only achieve 10% of what they aimed for, they will still benefit from the project.

PHASE 7: CONCLUSION

From the Monte Carlo Simulation data and the financial findings above it is clear that this can be a very profitable and successful endeavour for OMC to invest in. Besides the fact that OMC can expect to save approximately R27 million over the next three years there are other advantages as well which are listed below:

- Reduced inventory levels (in warehouses and production)
- Increased visibility and traceability of materials
- Improved control over materials
- Improved material flow patterns
- Increased production productivity and efficiency
- Sufficient data to balance production lines
- Reduced Obsolescence stock due to increased material visibility
- Reduced Lost time due to improved material placement and visibility
- Reduced material shortages

If these list of advantages are achieved the most valuable output for OMC will be increased capacity with the ability to increase their market share.

Recommendations:

From the study and evaluation of this project I recommend that OMC continue with the bar coding project and formulate a clear specification document before commencing to the design of the system. Although a lot of designs are shown and illustrated in this document they were only conceptual and the actual requirements and specifications should now be formulated.

From a Systems Engineering point the first two steps, customer need and conceptual design are complete. From the following systems life cycle diagram the project should now move to the following steps.

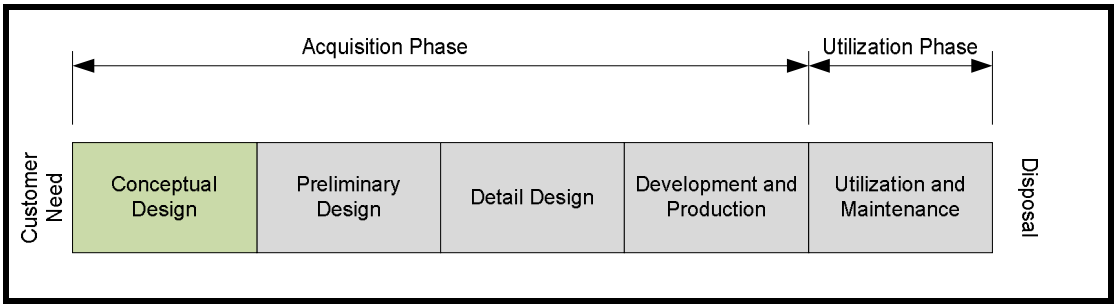


Figure 16: SYSTEM LIFE CYCLE DIAGRAM (BLANCHARD, B & FABRYCKY, J. :27p.)

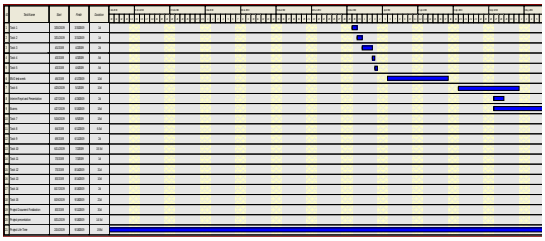
PHASE 8: FUTURE IMPROVEMENTS AND IMPLEMENTATION PLANS

After the bar code project have been implemented and in place the following projects can commence to improve processes at OMC even more.

- Form long term supplier relationships with all OMC suppliers
- Use all relevant data from Bar Code project and database to move towards JIT environment
- Start consulting at local suppliers to streamline the supply chain even more. End-to-end process improvement.

APPENDIX A

FIGURE 17: GANTT CHART



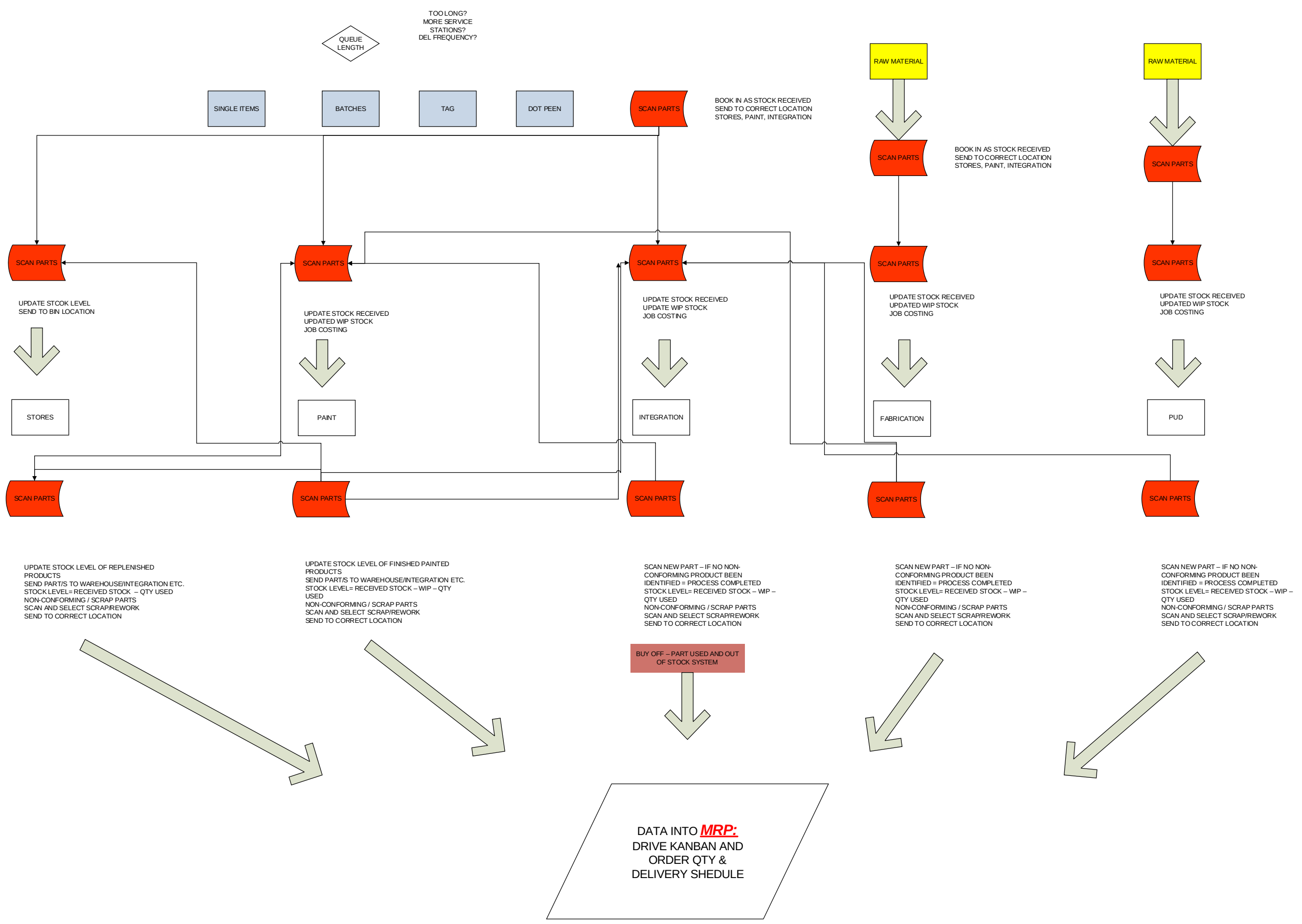
APPENDIX B

TABLE 14: INVENTORY LEVELS OF SELECTED PARTS

Item Description	Qty/stand	Items / vehicles	Current Stock Level
Transfer Case	4	1	10
Springs	8	4	24
Steering Box	4	1	19
Propshaft Front	5	1	19
Propshaft Rear	5	1	27
Propshaft Transfer Case	5	1	27
Shocks	72	8	144
U Bolts	20	4	204
Pump Flanges	1	2	6
Window Kits	7	7	14
Axles Rear	8	1	3
Axles Front	8	1	3
Transfer Case Covers	4	2	65
Hatches	16	2	60
Condensor LH	N/A	1	10
Condensor RH	N/A	1	10
Evaporator LH	N/A	1	5
Evaporator RH	N/A	1	5
Inverter Covers	N/A	1	70
Airtanks LH + RH	N/A	2	133

Front Digiracks	4	1	40
Front Seats	4	2	40
Nose Plates	10	1	8
Bonnet	9	1	22
Front Bins LH	N/A	1	11
Front Bins RH	N/A	1	11

FIGURE 18: CONCEPTUAL DESIGN B



Description of stock	GOODS RECEIVING	STORES	PAINT SHOP	INTEGRATION	FABRICATION	PUD
Initial/ Beginning Stock/inventory	LEFT OVER STOCK	LEFT OVER STOCK	LEFT OVER STOCK	LEFT OVER STOCK	LEFT OVER STOCK	LEFT OVER STOCK
STOCK RECEIVED [booked in stck]	# SCANNED	# SCANNED	# SCANNED	# SCANNED	# SCANNED	# SCANNED
WIP STOCK	QTY BOOKED OUT	QTY BOOKED OUT	QTY BOOKED OUT	QTY BOOKED OUT	QTY BOOKED OUT	QTY BOOKED OUT
STOCK REPLENISHED	STOCK USED	STOCK USED	STOCK USED	STOCK USED	STOCK USED	STOCK USED
NON-CONFORMING	# OF FAULTY PARTS	# OF FAULTY PARTS	# OF FAULTY PARTS	# OF FAULTY PARTS	# OF FAULTY PARTS	# OF FAULTY PARTS
REMAINING STOCK [ACTUAL STOCK]	REMAINING STOCK LEVEL [ACTUAL]=BEGINNING STOCK + STOCK RECEIVED - WIP STOCK - NON-CONFORMING STOCK	REMAINING STOCK LEVEL [ACTUAL]=BEGINNING STOCK + STOCK RECEIVED - WIP STOCK - NON-CONFORMING STOCK	REMAINING STOCK LEVEL [ACTUAL]=BEGINNING STOCK + STOCK RECEIVED - WIP STOCK - NON-CONFORMING STOCK	REMAINING STOCK LEVEL [ACTUAL]=BEGINNING STOCK + STOCK RECEIVED - WIP STOCK - NON-CONFORMING STOCK	REMAINING STOCK LEVEL [ACTUAL]=BEGINNING STOCK + STOCK RECEIVED - WIP STOCK - NON-CONFORMING STOCK	REMAINING STOCK LEVEL [ACTUAL]=BEGINNING STOCK + STOCK RECEIVED - WIP STOCK - NON-CONFORMING STOCK

PRODUCTS STRAIGHT TO LINE=	INTEGRATION REM
PRODUCTS TO STORES=	STORES REMAINING
PRODUCTS TO PAINT TO INTEGRATION=	PAINT + INTEGRATION
PRODUCTS TO STORES TO INTEGRATION=	STORES + INTEGRATION

ROUTING VIA PART #	Routing	Project number	Station or Destination
PI300238-PO1S3	Paint to Integration	Project 1	Station 3
I2390092-PO2S1	integration directly	Project 2	Station 1
SI3009543-PO1S5a	Stores then Integration	Project 1	Station 5a (sub-assy)
PSI200342-PO1S3	Paint to stores to integration	Project 1	Station 3

APPENDIX C

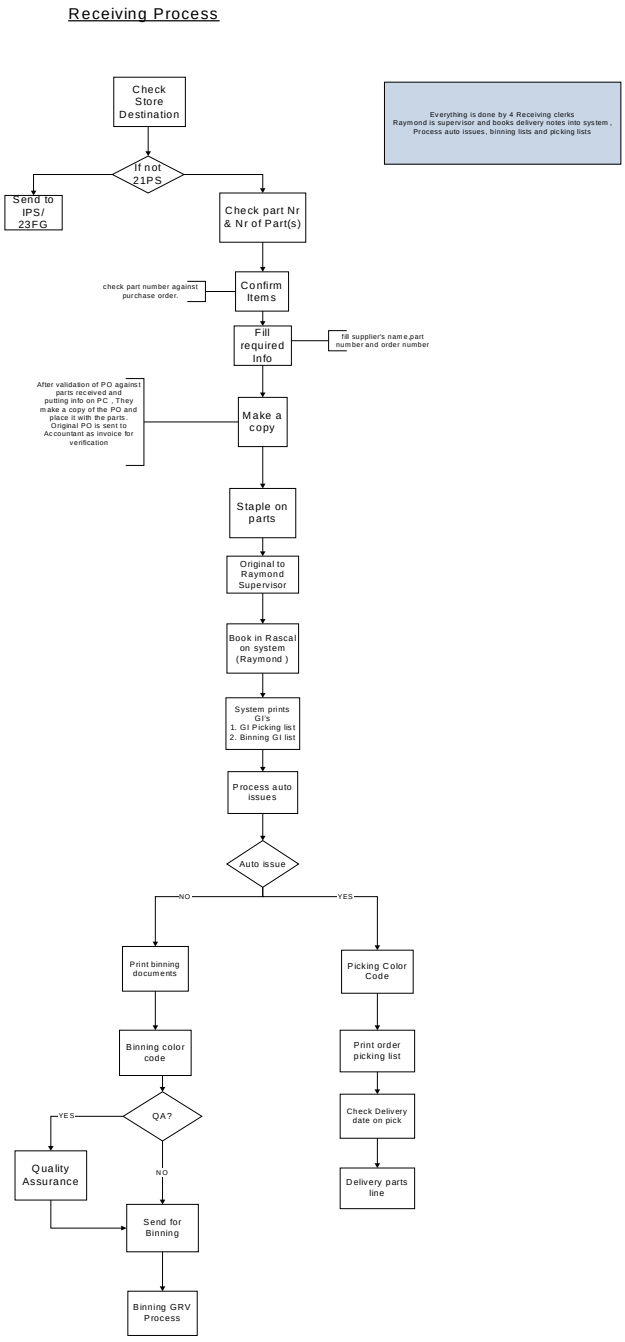


Figure 19: AS-IS RECEIVING PROCESS

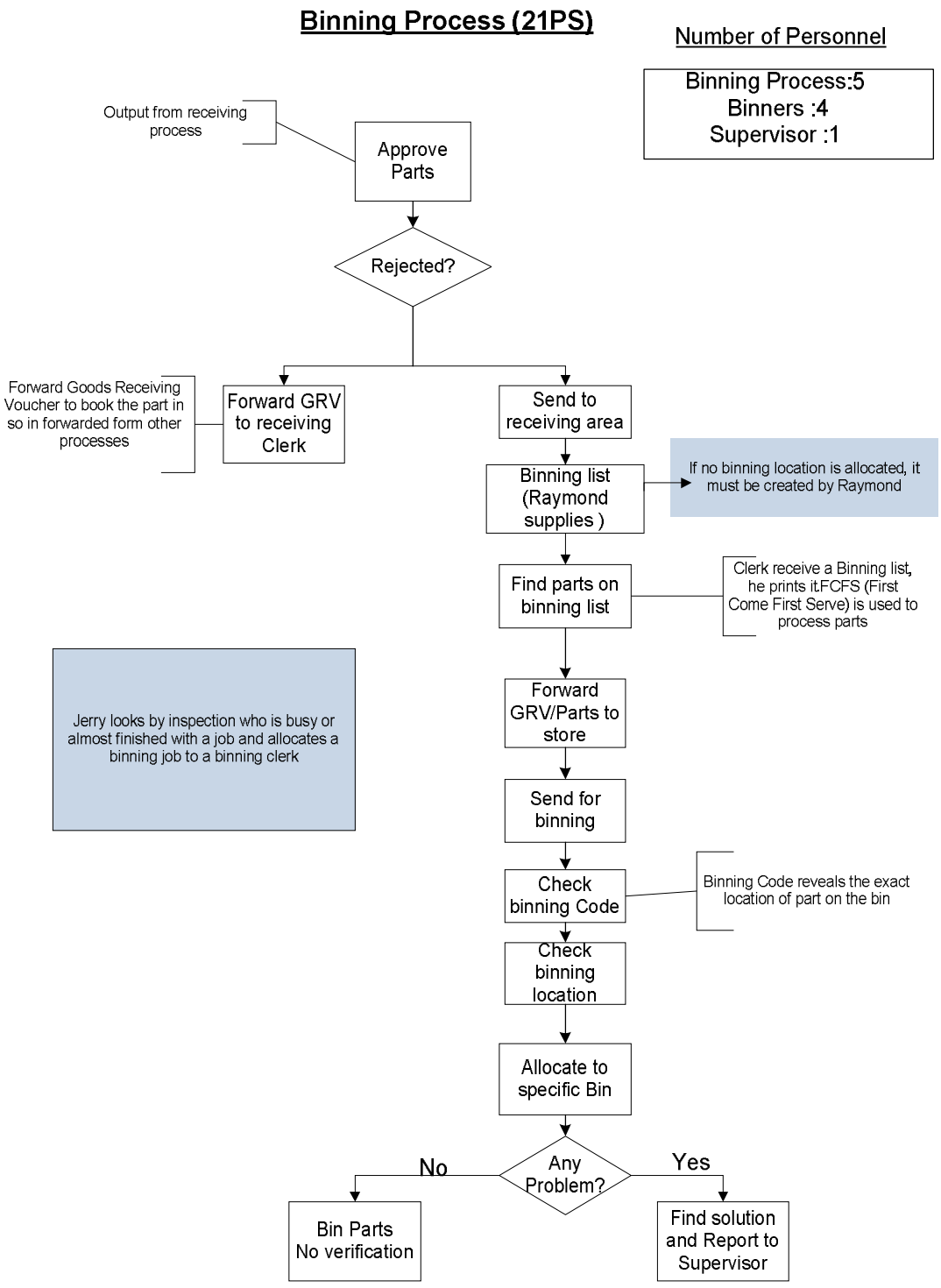


Figure 20: AS-IS BINNING PROCESS

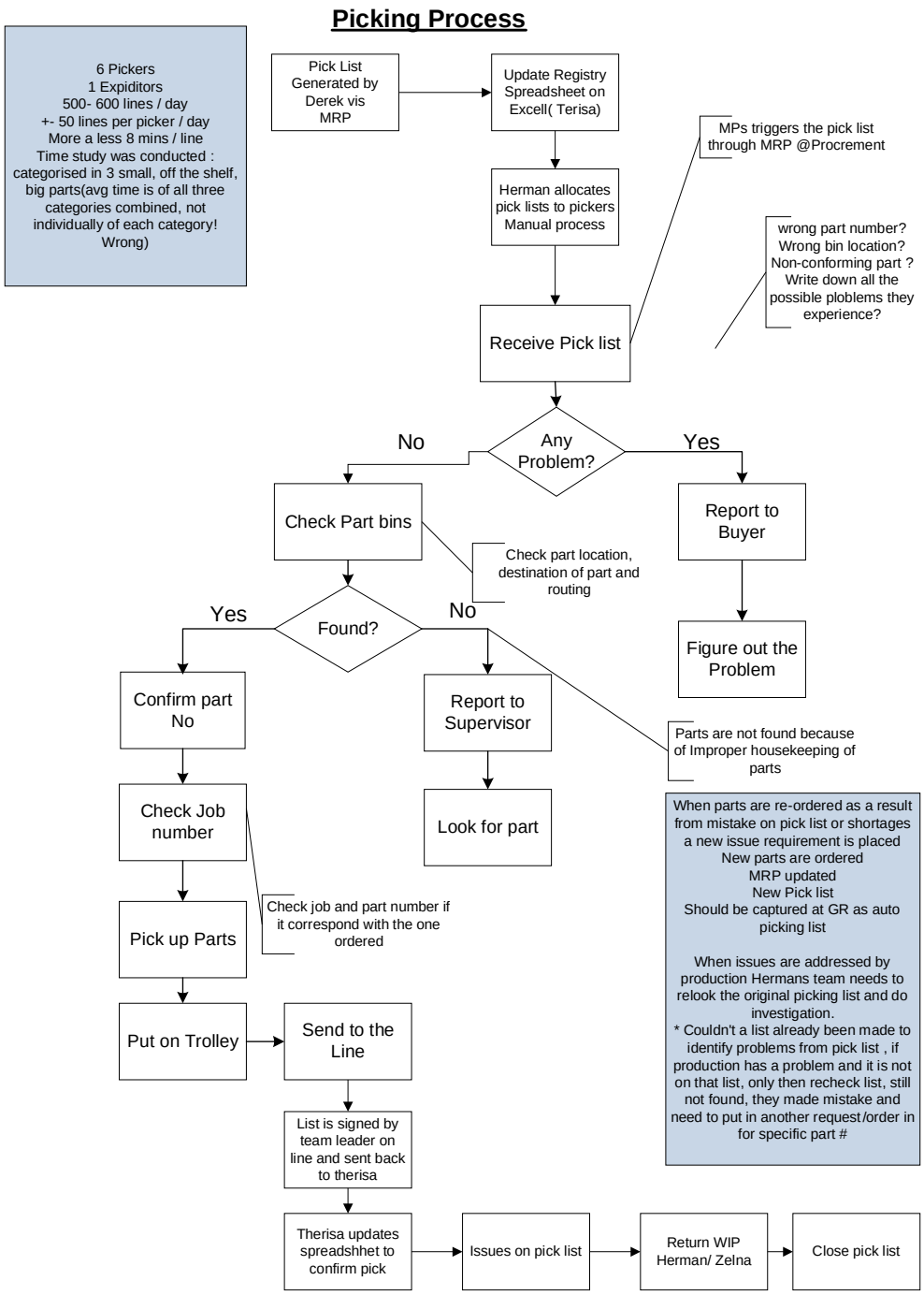


Figure 21:AS-IS PICKING PROCESS

APPENDIX D:

GOODS RECEIVING: PRODUCTION STORES

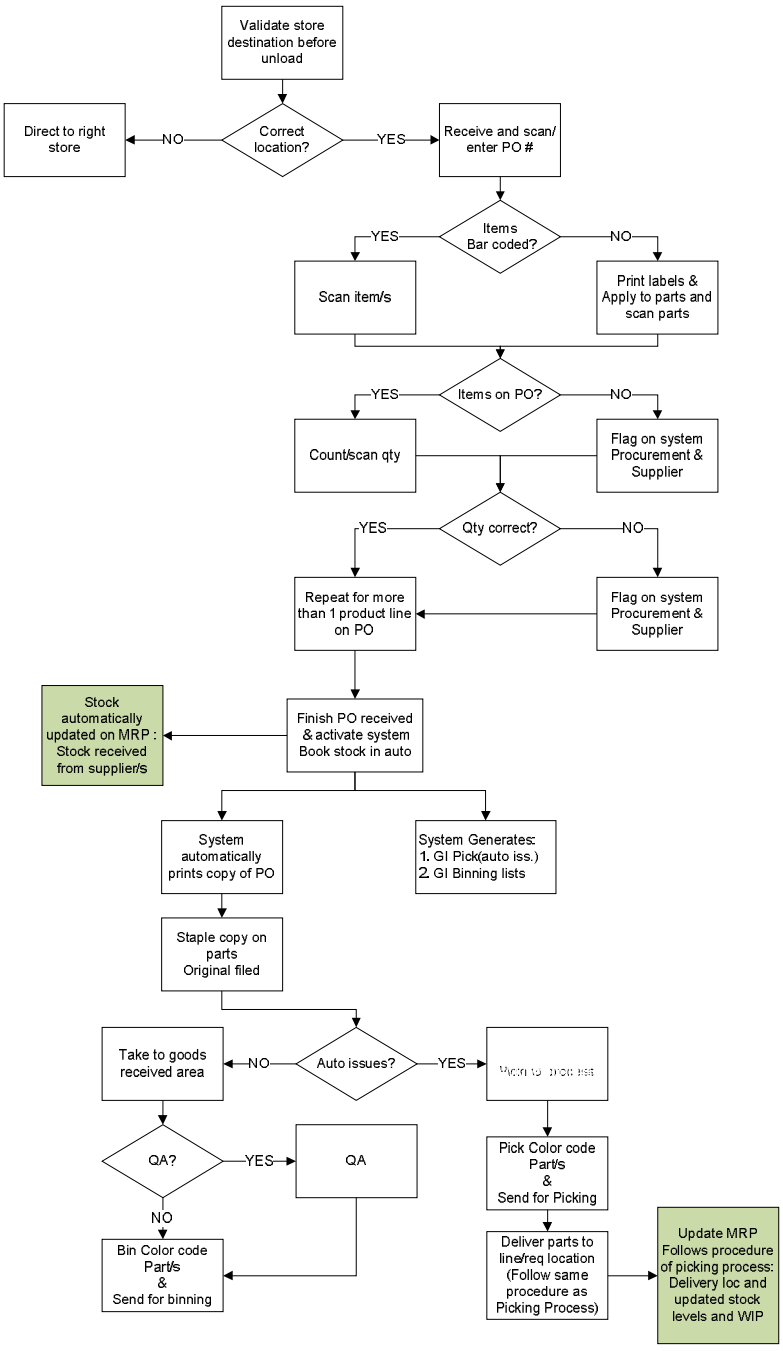


Figure 22: TO-BE RECEIVING PROCESS

BINNING: PRODUCTION STORES

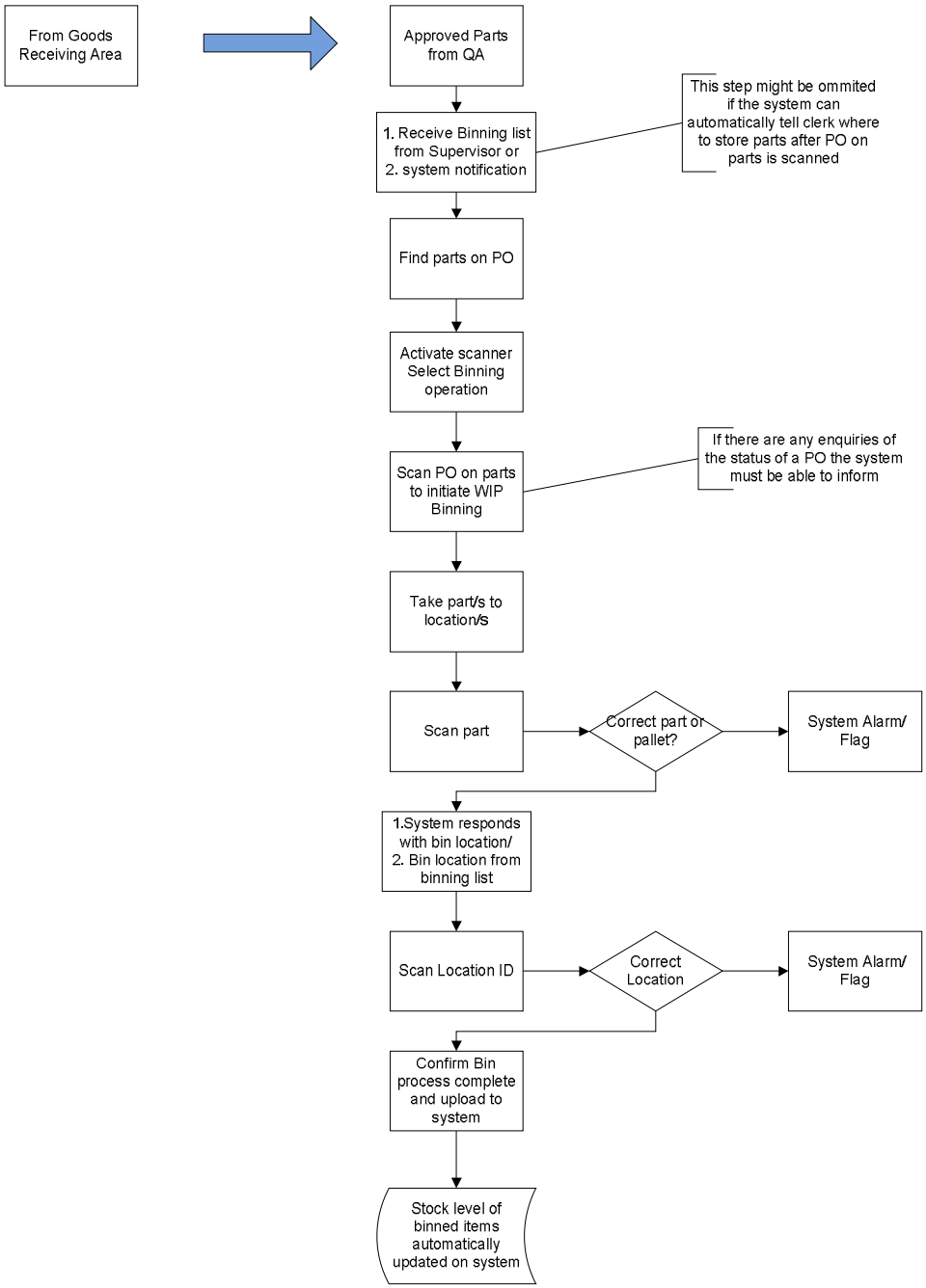


Figure 23: TO-BE BINNING PROCESS

PICKING PROCESS: BAR CODE

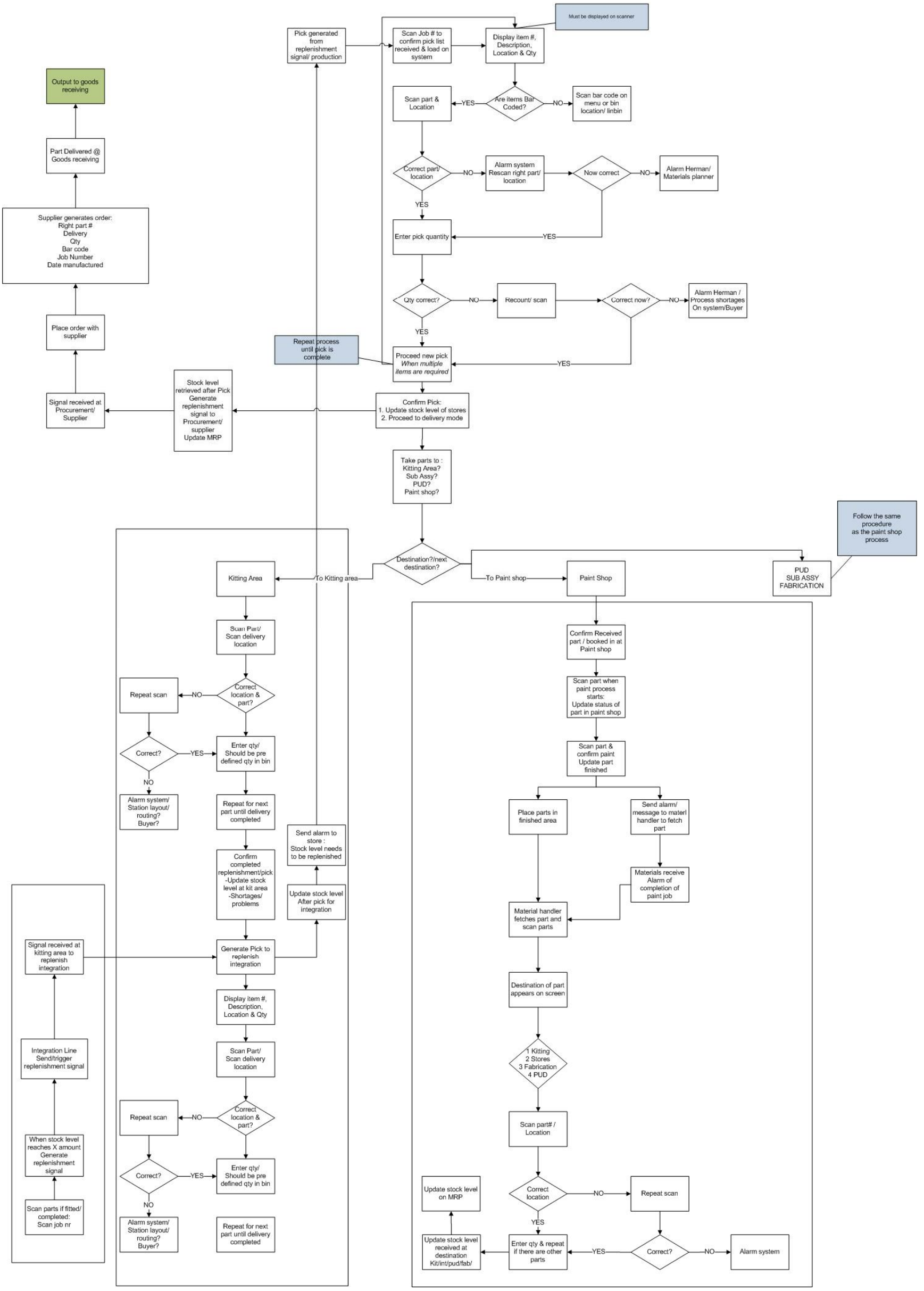


Figure 24:TO-BE PICKING PROCESS

APPENDIX E:

APPENDIX F:

Table 15: MONTE CARLO SIMULATION DATA

Montecarlo Simulation

Avg Hours Lost / Vehicle Min expected lost hours/vehicle Max expected lost hours/vehicle				122 Hours 45 Hours 155 Hours	Avg Rands lost in obsolescence stock Min expected Rands lost in obsolescence stock Max expected Avg Rands lost in obsolescence stock				R 63,754.58 R15,000.00 R112,000.00	Total Project Costs R1, 286, 214.24
Week	**Veh #**	**Probability (Min 145; Max 155)**	**Total Cost lost Hours @R300/hour**	**Estimated Cost of Obselescence Stock (Min R15, 000 ; Max R112,000)**	**Percentage of productivity improved (15% - 30%)**	**Amount saved on improved Productivity**	**Percentatage of reduced obsolescence stock**	**Amount saved on reduced obsolescence stock**	**Total Savings**	**Accumulative Savings**
1	1	99	R 29,700.00	R 38,021.00	22	R 6,534.00	17	R 6,463.57	R 12,997.57	R 12,997.57
3	2	106	R 31,800.00	R 32,175.00	16	R 5,088.00	28	R 9,009.00	R 14,097.00	R 27,094.57
4	3	119	R 35,700.00	R 77,087.00	28	R 9,996.00	25	R 19,271.75	R 29,267.75	R 56,362.32
4	4	101	R 30,300.00	R 72,959.00	30	R 9,090.00	24	R 17,510.16	R 26,600.16	R 82,962.48
5	5	152	R 45,600.00	R 107,312.00	22	R 10,032.00	24	R 25,754.88	R 35,786.88	R 118,749.36
5	6	149	R 44,700.00	R 21,703.00	16	R 7,152.00	19	R 4,123.57	R 11,275.57	R 130,024.93
5	7	121	R 36,300.00	R 99,423.00	15	R 5,445.00	22	R 21,873.06	R 27,318.06	R 157,342.99
5	8	122	R 36,600.00	R 34,844.00	30	R 10,980.00	24	R 8,362.56	R 19,342.56	R 176,685.55
6	9	139	R 41,700.00	R 108,630.00	21	R 8,757.00	26	R 28,243.80	R 37,000.80	R 213,686.35

6	10	145	R 43,500.00	R 79,567.00	26	R 11,310.00	16	R 12,730.72	R 24,040.72	R 237,727.07
6	11	79	R 23,700.00	R 29,201.00	22	R 5,214.00	28	R 8,176.28	R 13,390.28	R 251,117.35
6	12	134	R 40,200.00	R 40,879.00	21	R 8,442.00	23	R 9,402.17	R 17,844.17	R 268,961.52
6	13	99	R 29,700.00	R 17,477.00	18	R 5,346.00	23	R 4,019.71	R 9,365.71	R 278,327.23
7	14	150	R 45,000.00	R 15,567.00	27	R 12,150.00	28	R 4,358.76	R 16,508.76	R 294,835.99
7	15	73	R 21,900.00	R 101,311.00	19	R 4,161.00	22	R 22,288.42	R 26,449.42	R 321,285.41
7	16	129	R 38,700.00	R 39,563.00	26	R 10,062.00	18	R 7,121.34	R 17,183.34	R 338,468.75
7	17	66	R 19,800.00	R 29,686.00	30	R 5,940.00	24	R 7,124.64	R 13,064.64	R 351,533.39
7	18	106	R 31,800.00	R 67,489.00	30	R 9,540.00	28	R 18,896.92	R 28,436.92	R 379,970.31
7	19	108	R 32,400.00	R 110,020.00	29	R 9,396.00	15	R 16,503.00	R 25,899.00	R 405,869.31
8	20	133	R 39,900.00	R 58,140.00	23	R 9,177.00	27	R 15,697.80	R 24,874.80	R 430,744.11
8	21	130	R 39,000.00	R 93,653.00	28	R 10,920.00	21	R 19,667.13	R 30,587.13	R 461,331.24
8	22	116	R 34,800.00	R 61,551.00	27	R 9,396.00	21	R 12,925.71	R 22,321.71	R 483,652.95
8	23	108	R 32,400.00	R 108,038.00	29	R 9,396.00	23	R 24,848.74	R 34,244.74	R 517,897.69
8	24	112	R 33,600.00	R 42,349.00	24	R 8,064.00	19	R 8,046.31	R 16,110.31	R 534,008.00
8	25	138	R 41,400.00	R 103,648.00	26	R 10,764.00	15	R 15,547.20	R 26,311.20	R 560,319.20
9	26	146	R 43,800.00	R 42,442.00	26	R 11,388.00	19	R 8,063.98	R 19,451.98	R 579,771.18
9	27	104	R 31,200.00	R 91,199.00	29	R 9,048.00	24	R 21,887.76	R 30,935.76	R 610,706.94
9	28	150	R 45,000.00	R 36,461.00	30	R 13,500.00	29	R 10,573.69	R 24,073.69	R 634,780.63
9	29	105	R 31,500.00	R 30,164.00	26	R 8,190.00	26	R 7,842.64	R 16,032.64	R 650,813.27
9	30	79	R 23,700.00	R 26,352.00	20	R 4,740.00	29	R 7,642.08	R 12,382.08	R 663,195.35
10	31	67	R 20,100.00	R 95,669.00	29	R 5,829.00	15	R 14,350.35	R 20,179.35	R 683,374.70
10	32	135	R 40,500.00	R 100,580.00	16	R 6,480.00	21	R 21,121.80	R 27,601.80	R 710,976.50
10	33	140	R 42,000.00	R 22,243.00	29	R 12,180.00	30	R 6,672.90	R 18,852.90	R 729,829.40
10	34	129	R 38,700.00	R 38,871.00	30	R 11,610.00	21	R 8,162.91	R 19,772.91	R 749,602.31
10	35	118	R 35,400.00	R 71,867.00	30	R 10,620.00	21	R 15,092.07	R 25,712.07	R 775,314.38
11	36	141	R 42,300.00	R 64,906.00	17	R 7,191.00	20	R 12,981.20	R 20,172.20	R 795,486.58

11	37	69	R 20,700.00	R 54,685.00	19	R 3,933.00	30	R 16,405.50	R 20,338.50	R 815,825.08
11	38	94	R 28,200.00	R 29,305.00	27	R 7,614.00	26	R 7,619.30	R 15,233.30	R 831,058.38
11	39	103	R 30,900.00	R 57,182.00	23	R 7,107.00	26	R 14,867.32	R 21,974.32	R 853,032.70
11	40	91	R 27,300.00	R 33,630.00	30	R 8,190.00	15	R 5,044.50	R 13,234.50	R 866,267.20
11	41	69	R 20,700.00	R 15,812.00	28	R 5,796.00	18	R 2,846.16	R 8,642.16	R 874,909.36
12	42	86	R 25,800.00	R 92,960.00	29	R 7,482.00	15	R 13,944.00	R 21,426.00	R 896,335.36
12	43	71	R 21,300.00	R 81,228.00	30	R 6,390.00	25	R 20,307.00	R 26,697.00	R 923,032.36
12	44	67	R 20,100.00	R 68,943.00	19	R 3,819.00	16	R 11,030.88	R 14,849.88	R 937,882.24
12	45	155	R 46,500.00	R 101,108.00	26	R 12,090.00	25	R 25,277.00	R 37,367.00	R 975,249.24
12	46	106	R 31,800.00	R 16,297.00	25	R 7,950.00	28	R 4,563.16	R 12,513.16	R 987,762.40
12	47	97	R 29,100.00	R 108,504.00	16	R 4,656.00	15	R 16,275.60	R 20,931.60	R 1,008,694.00
13	48	147	R 44,100.00	R 106,841.00	30	R 13,230.00	27	R 28,847.07	R 42,077.07	R 1,050,771.07
13	49	137	R 41,100.00	R 88,352.00	27	R 11,097.00	27	R 23,855.04	R 34,952.04	R 1,085,723.11
13	50	121	R 36,300.00	R 99,554.00	22	R 7,986.00	28	R 27,875.12	R 35,861.12	R 1,121,584.23
13	51	118	R 35,400.00	R 74,263.00	26	R 9,204.00	24	R 17,823.12	R 27,027.12	R 1,148,611.35
13	52	98	R 29,400.00	R 48,454.00	26	R 7,644.00	29	R 14,051.66	R 21,695.66	R 1,170,307.01
13	53	152	R 45,600.00	R 36,454.00	28	R 12,768.00	16	R 5,832.64	R 18,600.64	R 1,188,907.65
14	54	111	R 33,300.00	R 62,272.00	25	R 8,325.00	25	R 15,568.00	R 23,893.00	R 1,212,800.65
14	55	136	R 40,800.00	R 32,872.00	15	R 6,120.00	23	R 7,560.56	R 13,680.56	R 1,226,481.21
14	56	96	R 28,800.00	R 19,480.00	18	R 5,184.00	15	R 2,922.00	R 8,106.00	R 1,234,587.21
14	57	105	R 31,500.00	R 16,785.00	27	R 8,505.00	27	R 4,531.95	R 13,036.95	R 1,247,624.16
14	58	86	R 25,800.00	R 111,844.00	25	R 6,450.00	19	R 21,250.36	R 27,700.36	R 1,275,324.52
14	59	94	R 28,200.00	R 109,205.00	22	R 6,204.00	29	R 31,669.45	R 37,873.45	R 1,313,197.97
15	60	131	R 39,300.00	R 89,741.00	18	R 7,074.00	18	R 16,153.38	R 23,227.38	R 1,336,425.35
15	61	136	R 40,800.00	R 99,280.00	18	R 7,344.00	18	R 17,870.40	R 25,214.40	R 1,361,639.75
15	62	134	R 40,200.00	R 74,456.00	20	R 8,040.00	21	R 15,635.76	R 23,675.76	R 1,385,315.51
15	63	74	R 22,200.00	R 58,056.00	17	R 3,774.00	15	R 8,708.40	R 12,482.40	R 1,397,797.91

15	64	107	R 32,100.00	R 50,502.00	25	R 8,025.00	29	R 14,645.58	R 22,670.58	R 1,420,468.49
15	65	141	R 42,300.00	R 43,004.00	30	R 12,690.00	16	R 6,880.64	R 19,570.64	R 1,440,039.13
16	66	95	R 28,500.00	R 70,755.00	26	R 7,410.00	25	R 17,688.75	R 25,098.75	R 1,465,137.88
16	67	99	R 29,700.00	R 45,132.00	16	R 4,752.00	30	R 13,539.60	R 18,291.60	R 1,483,429.48
16	68	110	R 33,000.00	R 98,408.00	30	R 9,900.00	29	R 28,538.32	R 38,438.32	R 1,521,867.80
16	69	131	R 39,300.00	R 90,503.00	18	R 7,074.00	26	R 23,530.78	R 30,604.78	R 1,552,472.58
16	70	68	R 20,400.00	R 95,219.00	26	R 5,304.00	21	R 19,995.99	R 25,299.99	R 1,577,772.57
16	71	90	R 27,000.00	R 60,153.00	23	R 6,210.00	26	R 15,639.78	R 21,849.78	R 1,599,622.35
16	72	80	R 24,000.00	R 30,352.00	16	R 3,840.00	29	R 8,802.08	R 12,642.08	R 1,612,264.43
17	73	103	R 30,900.00	R 89,819.00	29	R 8,961.00	27	R 24,251.13	R 33,212.13	R 1,645,476.56
17	74	141	R 42,300.00	R 110,521.00	27	R 11,421.00	17	R 18,788.57	R 30,209.57	R 1,675,686.13
17	75	143	R 42,900.00	R 43,853.00	26	R 11,154.00	28	R 12,278.84	R 23,432.84	R 1,699,118.97
17	76	125	R 37,500.00	R 32,622.00	30	R 11,250.00	27	R 8,807.94	R 20,057.94	R 1,719,176.91
17	77	133	R 39,900.00	R 28,977.00	16	R 6,384.00	22	R 6,374.94	R 12,758.94	R 1,731,935.85
17	78	139	R 41,700.00	R 18,029.00	21	R 8,757.00	23	R 4,146.67	R 12,903.67	R 1,744,839.52
18	79	135	R 40,500.00	R 24,916.00	22	R 8,910.00	25	R 6,229.00	R 15,139.00	R 1,759,978.52
18	80	140	R 42,000.00	R 52,196.00	22	R 9,240.00	16	R 8,351.36	R 17,591.36	R 1,777,569.88
18	81	148	R 44,400.00	R 67,852.00	27	R 11,988.00	15	R 10,177.80	R 22,165.80	R 1,799,735.68
18	82	95	R 28,500.00	R 59,884.00	17	R 4,845.00	18	R 10,779.12	R 15,624.12	R 1,815,359.80
18	83	134	R 40,200.00	R 111,808.00	15	R 6,030.00	18	R 20,125.44	R 26,155.44	R 1,841,515.24
18	84	76	R 22,800.00	R 80,089.00	23	R 5,244.00	26	R 20,823.14	R 26,067.14	R 1,867,582.38
19	85	112	R 33,600.00	R 71,170.00	27	R 9,072.00	30	R 21,351.00	R 30,423.00	R 1,898,005.38
19	86	109	R 32,700.00	R 80,510.00	27	R 8,829.00	28	R 22,542.80	R 31,371.80	R 1,929,377.18
19	87	84	R 25,200.00	R 62,274.00	23	R 5,796.00	30	R 18,682.20	R 24,478.20	R 1,953,855.38
19	88	120	R 36,000.00	R 57,460.00	17	R 6,120.00	18	R 10,342.80	R 16,462.80	R 1,970,318.18
19	89	72	R 21,600.00	R 20,280.00	18	R 3,888.00	21	R 4,258.80	R 8,146.80	R 1,978,464.98
20	90	121	R 36,300.00	R 50,537.00	16	R 5,808.00	18	R 9,096.66	R 14,904.66	R 1,993,369.64

20	91	74	R 22,200.00	R 101,464.00	26	R 5,772.00	27	R 27,395.28	R 33,167.28	R 2,026,536.92
20	92	126	R 37,800.00	R 75,018.00	30	R 11,340.00	21	R 15,753.78	R 27,093.78	R 2,053,630.70
20	93	143	R 42,900.00	R 75,372.00	22	R 9,438.00	23	R 17,335.56	R 26,773.56	R 2,080,404.26
20	94	143	R 42,900.00	R 84,806.00	16	R 6,864.00	30	R 25,441.80	R 32,305.80	R 2,112,710.06
21	95	135	R 40,500.00	R 27,275.00	19	R 7,695.00	18	R 4,909.50	R 12,604.50	R 2,125,314.56
21	96	109	R 32,700.00	R 67,148.00	20	R 6,540.00	19	R 12,758.12	R 19,298.12	R 2,144,612.68
21	97	119	R 35,700.00	R 44,704.00	20	R 7,140.00	18	R 8,046.72	R 15,186.72	R 2,159,799.40
21	98	67	R 20,100.00	R 43,528.00	26	R 5,226.00	30	R 13,058.40	R 18,284.40	R 2,178,083.80
21	99	98	R 29,400.00	R 95,449.00	17	R 4,998.00	23	R 21,953.27	R 26,951.27	R 2,205,035.07
22	100	82	R 24,600.00	R 49,530.00	28	R 6,888.00	16	R 7,924.80	R 14,812.80	R 2,219,847.87
22	101	147	R 44,100.00	R 42,344.00	19	R 8,379.00	24	R 10,162.56	R 18,541.56	R 2,238,389.43
22	102	96	R 28,800.00	R 103,319.00	30	R 8,640.00	15	R 15,497.85	R 24,137.85	R 2,262,527.28
22	103	104	R 31,200.00	R 47,543.00	25	R 7,800.00	16	R 7,606.88	R 15,406.88	R 2,277,934.16
22	104	132	R 39,600.00	R 82,472.00	25	R 9,900.00	25	R 20,618.00	R 30,518.00	R 2,308,452.16
23	105	94	R 28,200.00	R 88,706.00	26	R 7,332.00	17	R 15,080.02	R 22,412.02	R 2,330,864.18
23	106	141	R 42,300.00	R 85,651.00	27	R 11,421.00	18	R 15,417.18	R 26,838.18	R 2,357,702.36
23	107	82	R 24,600.00	R 49,535.00	29	R 7,134.00	30	R 14,860.50	R 21,994.50	R 2,379,696.86
23	108	123	R 36,900.00	R 86,019.00	29	R 10,701.00	17	R 14,623.23	R 25,324.23	R 2,405,021.09
23	109	146	R 43,800.00	R 65,792.00	25	R 10,950.00	20	R 13,158.40	R 24,108.40	R 2,429,129.49
24	110	77	R 23,100.00	R 104,345.00	17	R 3,927.00	17	R 17,738.65	R 21,665.65	R 2,450,795.14
24	111	129	R 38,700.00	R 87,762.00	18	R 6,966.00	21	R 18,430.02	R 25,396.02	R 2,476,191.16
24	112	65	R 19,500.00	R 63,272.00	19	R 3,705.00	28	R 17,716.16	R 21,421.16	R 2,497,612.32
24	113	145	R 43,500.00	R 105,493.00	24	R 10,440.00	24	R 25,318.32	R 35,758.32	R 2,533,370.64
24	114	141	R 42,300.00	R 41,159.00	21	R 8,883.00	18	R 7,408.62	R 16,291.62	R 2,549,662.26
25	115	68	R 20,400.00	R 92,947.00	19	R 3,876.00	25	R 23,236.75	R 27,112.75	R 2,576,775.01
25	116	75	R 22,500.00	R 66,461.00	24	R 5,400.00	25	R 16,615.25	R 22,015.25	R 2,598,790.26
25	117	70	R 21,000.00	R 78,704.00	20	R 4,200.00	25	R 19,676.00	R 23,876.00	R 2,622,666.26

25	118	106	R 31,800.00	R 28,864.00	19	R 6,042.00	18	R 5,195.52	R 11,237.52	R 2,633,903.78
25	119	86	R 25,800.00	R 30,586.00	17	R 4,386.00	30	R 9,175.80	R 13,561.80	R 2,647,465.58
26	120	78	R 23,400.00	R 71,931.00	23	R 5,382.00	23	R 16,544.13	R 21,926.13	R 2,669,391.71
26	121	121	R 36,300.00	R 101,503.00	21	R 7,623.00	18	R 18,270.54	R 25,893.54	R 2,695,285.25
26	122	90	R 27,000.00	R 53,006.00	20	R 5,400.00	27	R 14,311.62	R 19,711.62	R 2,714,996.87
26	123	134	R 40,200.00	R 34,888.00	25	R 10,050.00	18	R 6,279.84	R 16,329.84	R 2,731,326.71
26	124	101	R 30,300.00	R 29,374.00	28	R 8,484.00	21	R 6,168.54	R 14,652.54	R 2,745,979.25
27	125	102	R 30,600.00	R 33,392.00	17	R 5,202.00	17	R 5,676.64	R 10,878.64	R 2,756,857.89
27	126	109	R 32,700.00	R 71,373.00	21	R 6,867.00	28	R 19,984.44	R 26,851.44	R 2,783,709.33
27	127	122	R 36,600.00	R 30,409.00	16	R 5,856.00	20	R 6,081.80	R 11,937.80	R 2,795,647.13
27	128	84	R 25,200.00	R 107,981.00	25	R 6,300.00	22	R 23,755.82	R 30,055.82	R 2,825,702.95
27	129	110	R 33,000.00	R 84,175.00	19	R 6,270.00	15	R 12,626.25	R 18,896.25	R 2,844,599.20
28	130	81	R 24,300.00	R 34,901.00	30	R 7,290.00	25	R 8,725.25	R 16,015.25	R 2,860,614.45
28	131	133	R 39,900.00	R 63,529.00	27	R 10,773.00	17	R 10,799.93	R 21,572.93	R 2,882,187.38
28	132	118	R 35,400.00	R 20,846.00	17	R 6,018.00	21	R 4,377.66	R 10,395.66	R 2,892,583.04
28	133	147	R 44,100.00	R 52,948.00	21	R 9,261.00	23	R 12,178.04	R 21,439.04	R 2,914,022.08
28	134	130	R 39,000.00	R 83,297.00	19	R 7,410.00	27	R 22,490.19	R 29,900.19	R 2,943,922.27
29	135	155	R 46,500.00	R 107,197.00	21	R 9,765.00	18	R 19,295.46	R 29,060.46	R 2,972,982.73
29	136	144	R 43,200.00	R 94,085.00	22	R 9,504.00	22	R 20,698.70	R 30,202.70	R 3,003,185.43
29	137	96	R 28,800.00	R 79,854.00	25	R 7,200.00	17	R 13,575.18	R 20,775.18	R 3,023,960.61
29	138	69	R 20,700.00	R 95,851.00	30	R 6,210.00	27	R 25,879.77	R 32,089.77	R 3,056,050.38
29	139	119	R 35,700.00	R 77,012.00	17	R 6,069.00	21	R 16,172.52	R 22,241.52	R 3,078,291.90
30	140	121	R 36,300.00	R 64,149.00	20	R 7,260.00	19	R 12,188.31	R 19,448.31	R 3,097,740.21
30	141	96	R 28,800.00	R 81,675.00	29	R 8,352.00	21	R 17,151.75	R 25,503.75	R 3,123,243.96
30	142	103	R 30,900.00	R 28,629.00	27	R 8,343.00	22	R 6,298.38	R 14,641.38	R 3,137,885.34
30	143	95	R 28,500.00	R 77,093.00	24	R 6,840.00	22	R 16,960.46	R 23,800.46	R 3,161,685.80
30	144	134	R 40,200.00	R 21,910.00	30	R 12,060.00	25	R 5,477.50	R 17,537.50	R 3,179,223.30

31	145	155	R 46,500.00	R 24,928.00	23	R 10,695.00	18	R 4,487.04	R 15,182.04	R 3,194,405.34
31	146	141	R 42,300.00	R 85,497.00	18	R 7,614.00	25	R 21,374.25	R 28,988.25	R 3,223,393.59
31	147	115	R 34,500.00	R 82,879.00	21	R 7,245.00	29	R 24,034.91	R 31,279.91	R 3,254,673.50
31	148	138	R 41,400.00	R 89,760.00	21	R 8,694.00	25	R 22,440.00	R 31,134.00	R 3,285,807.50
31	149	127	R 38,100.00	R 22,040.00	18	R 6,858.00	21	R 4,628.40	R 11,486.40	R 3,297,293.90
32	150	142	R 42,600.00	R 107,344.00	27	R 11,502.00	20	R 21,468.80	R 32,970.80	R 3,330,264.70
32	151	125	R 37,500.00	R 42,948.00	18	R 6,750.00	20	R 8,589.60	R 15,339.60	R 3,345,604.30
32	152	154	R 46,200.00	R 96,250.00	27	R 12,474.00	28	R 26,950.00	R 39,424.00	R 3,385,028.30
32	153	143	R 42,900.00	R 80,549.00	29	R 12,441.00	21	R 16,915.29	R 29,356.29	R 3,414,384.59
32	154	127	R 38,100.00	R 95,427.00	30	R 11,430.00	29	R 27,673.83	R 39,103.83	R 3,453,488.42
33	155	155	R 46,500.00	R 96,829.00	30	R 13,950.00	24	R 23,238.96	R 37,188.96	R 3,490,677.38
33	156	74	R 22,200.00	R 83,751.00	25	R 5,550.00	19	R 15,912.69	R 21,462.69	R 3,512,140.07
33	157	136	R 40,800.00	R 83,573.00	30	R 12,240.00	24	R 20,057.52	R 32,297.52	R 3,544,437.59
33	158	144	R 43,200.00	R 31,549.00	20	R 8,640.00	18	R 5,678.82	R 14,318.82	R 3,558,756.41
33	159	103	R 30,900.00	R 43,563.00	15	R 4,635.00	30	R 13,068.90	R 17,703.90	R 3,576,460.31
34	160	85	R 25,500.00	R 54,775.00	24	R 6,120.00	21	R 11,502.75	R 17,622.75	R 3,594,083.06
34	161	135	R 40,500.00	R 106,765.00	19	R 7,695.00	26	R 27,758.90	R 35,453.90	R 3,629,536.96
34	162	112	R 33,600.00	R 87,275.00	21	R 7,056.00	30	R 26,182.50	R 33,238.50	R 3,662,775.46
34	163	129	R 38,700.00	R 68,491.00	25	R 9,675.00	29	R 19,862.39	R 29,537.39	R 3,692,312.85
34	164	105	R 31,500.00	R 84,900.00	27	R 8,505.00	21	R 17,829.00	R 26,334.00	R 3,718,646.85
35	165	155	R 46,500.00	R 50,893.00	15	R 6,975.00	28	R 14,250.04	R 21,225.04	R 3,739,871.89
35	166	105	R 31,500.00	R 38,484.00	28	R 8,820.00	19	R 7,311.96	R 16,131.96	R 3,756,003.85
35	167	79	R 23,700.00	R 85,516.00	26	R 6,162.00	26	R 22,234.16	R 28,396.16	R 3,784,400.01
35	168	84	R 25,200.00	R 75,896.00	28	R 7,056.00	24	R 18,215.04	R 25,271.04	R 3,809,671.05
35	169	127	R 38,100.00	R 97,902.00	29	R 11,049.00	24	R 23,496.48	R 34,545.48	R 3,844,216.53
36	170	106	R 31,800.00	R 45,204.00	30	R 9,540.00	24	R 10,848.96	R 20,388.96	R 3,864,605.49
36	171	150	R 45,000.00	R 19,721.00	15	R 6,750.00	27	R 5,324.67	R 12,074.67	R 3,876,680.16

36	172	145	R 43,500.00	R 74,438.00	20	R 8,700.00	25	R 18,609.50	R 27,309.50	R 3,903,989.66
36	173	100	R 30,000.00	R 101,880.00	23	R 6,900.00	17	R 17,319.60	R 24,219.60	R 3,928,209.26
36	174	66	R 19,800.00	R 18,852.00	30	R 5,940.00	28	R 5,278.56	R 11,218.56	R 3,939,427.82
37	175	119	R 35,700.00	R 83,252.00	23	R 8,211.00	16	R 13,320.32	R 21,531.32	R 3,960,959.14
37	176	118	R 35,400.00	R 36,777.00	20	R 7,080.00	22	R 8,090.94	R 15,170.94	R 3,976,130.08
37	177	118	R 35,400.00	R 40,559.00	16	R 5,664.00	17	R 6,895.03	R 12,559.03	R 3,988,689.11
37	178	130	R 39,000.00	R 29,040.00	27	R 10,530.00	27	R 7,840.80	R 18,370.80	R 4,007,059.91
37	179	95	R 28,500.00	R 82,628.00	18	R 5,130.00	27	R 22,309.56	R 27,439.56	R 4,034,499.47
38	180	76	R 22,800.00	R 103,223.00	26	R 5,928.00	28	R 28,902.44	R 34,830.44	R 4,069,329.91
38	181	114	R 34,200.00	R 43,451.00	23	R 7,866.00	25	R 10,862.75	R 18,728.75	R 4,088,058.66
38	182	122	R 36,600.00	R 25,114.00	19	R 6,954.00	21	R 5,273.94	R 12,227.94	R 4,100,286.60
38	183	147	R 44,100.00	R 75,401.00	19	R 8,379.00	29	R 21,866.29	R 30,245.29	R 4,130,531.89
38	184	103	R 30,900.00	R 46,814.00	28	R 8,652.00	23	R 10,767.22	R 19,419.22	R 4,149,951.11
39	185	119	R 35,700.00	R 80,993.00	15	R 5,355.00	27	R 21,868.11	R 27,223.11	R 4,177,174.22
39	186	113	R 33,900.00	R 49,182.00	19	R 6,441.00	21	R 10,328.22	R 16,769.22	R 4,193,943.44
39	187	129	R 38,700.00	R 56,931.00	20	R 7,740.00	17	R 9,678.27	R 17,418.27	R 4,211,361.71
39	188	93	R 27,900.00	R 71,550.00	26	R 7,254.00	30	R 21,465.00	R 28,719.00	R 4,240,080.71
39	189	81	R 24,300.00	R 87,456.00	15	R 3,645.00	24	R 20,989.44	R 24,634.44	R 4,264,715.15
40	190	131	R 39,300.00	R 29,368.00	27	R 10,611.00	20	R 5,873.60	R 16,484.60	R 4,281,199.75
40	191	117	R 35,100.00	R 60,953.00	18	R 6,318.00	16	R 9,752.48	R 16,070.48	R 4,297,270.23
40	192	111	R 33,300.00	R 52,364.00	20	R 6,660.00	15	R 7,854.60	R 14,514.60	R 4,311,784.83
40	193	77	R 23,100.00	R 46,365.00	25	R 5,775.00	18	R 8,345.70	R 14,120.70	R 4,325,905.53
40	194	93	R 27,900.00	R 89,670.00	22	R 6,138.00	24	R 21,520.80	R 27,658.80	R 4,353,564.33
41	195	80	R 24,000.00	R 103,425.00	27	R 6,480.00	18	R 18,616.50	R 25,096.50	R 4,378,660.83
41	196	115	R 34,500.00	R 84,648.00	28	R 9,660.00	24	R 20,315.52	R 29,975.52	R 4,408,636.35
41	197	78	R 23,400.00	R 27,996.00	20	R 4,680.00	23	R 6,439.08	R 11,119.08	R 4,419,755.43
41	198	111	R 33,300.00	R 35,775.00	28	R 9,324.00	24	R 8,586.00	R 17,910.00	R 4,437,665.43

41	199	115	R 34,500.00	R 45,515.00	26	R 8,970.00	17	R 7,737.55	R 16,707.55	R 4,454,372.98
42	200	119	R 35,700.00	R 78,087.00	16	R 5,712.00	30	R 23,426.10	R 29,138.10	R 4,483,511.08
				Total Savings		**R 1,570,596.00**		**R 2,912,915.08**	**R 4,483,511.08**	
				Averages		**R 7,852.98**		**R 14,564.58**	**R 22,417.56**	
				Std Deviation		**R 2,349.25**		**R 7,005.27**	**R 7,506.13**	

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