Using Tools and Techniques to Optimize the Body Shop at Nissan, Rosslyn

By

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EXECUTIVE SUMMARY

Congestion is a problem not unfamiliar to any manufacturing plant. This is also the case in the Body Shop area for the X90 project at Nissan.

Problems that arise from congestion include a longer lead time, safety hazards, over-packing, over manufacturing, frustrated operators and an overall less productive manufacturing line.

Many tools and techniques are already in place to address congestion, such as Lean Manufacturing, Methods Engineering, Six Sigma, Kanban pull system, TOC and other industrial engineering concepts. Some of these will be investigated in-depth in this paper's Literature Review to determine ways to improve on the current manufacturing line in the Nissan Body Shop. To understand the overhead problems, analysis will be done on specific workstations.

Journals and research done by peers in the Industrial Engineering field are reviewed to determine the best tools for solving issues highlighted in the Problem Statement. An action plan on how each problem will be addressed is included in the Solutions Methodology chapter of this document.

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KEY WORDS

- Body shop
- Congestion
- Facility planning
- Housekeeping
- Lean manufacturing
- Line-side storage
- Material handling
- Methods engineering
- Nissan
- Repack
- Work stations

ABBREVIATIONS

BOM	Bill of Material
FIFO	First In First Out
JIT	Just in Time
JIS	Just in Sequence
m^2	Square Meters
OSHA	Occupational Safety and Health Administration
SC	Supply Chain
SLS	Schnellecke Logistic Services
WIP	Work In Progress

CHAPTER 1: INTRODUCTION

Background

According to www.southafrica.info, the motor industry accounts for around 10% of South Africa's manufacturing exports, making it a crucial component in the country's economy. One of the major motor companies responsible for this figure, is Nissan.

For my final year project, I will be working alongside Schnellecke Logistic Services at the Rosslyn plant of Nissan to improve aspects of their supply chain in which they have identified problems. The Schnellecke office is situated inside the Nissan plant, and consists of a team of industrial engineers.

Some of the services that Schnellecke Logistics provide to Nissan include:

- Supply to the Paint Shop, Body Shop, Assembly Hall and Kitting Area
- Line feed for various models (using techniques for mixed-model assembly lines)
- Devanning containers
- Receiving CKD containers and local parts
- Downsizing boxes into smaller bins
- Line supply via JIS, KANBAN, Milk run, KIT-supply and Sequential supply
- Line layouts, design and maintenance of facilities.

The product under investigation is the X90 project (Renault Sandero (B90) and Nissan NP200 (U90)). These models mentioned have a current worth of between R90 000 to R170 000, with almost 140 units produced every day at this Nissan plant of Rosslyn.

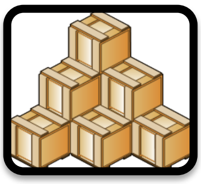
Problem Statement

Multiple problems in the Body Shop for the X90 project have been overlooked for a long time. Many problems are encountered, mainly because of congestion in the area. There is currently no effective system in place for repacking and line-feeding of parts. A summary of the problems are given in Figure 1: Problems identified.

Congestion leads to longer lead times, safety hazards and a chaotic work space. Line-side storage of Work In Progress should be considered as a main point of investigation and redesign. Boxes are spread over a very limited area of space. The use of vertical height for short-term storage has not been considered as a means of solving the problem of lacking space, even though this option holds many benefits. The design of racking next to the assembly line should be improved on to suit the current size and shape of parts that are stored temporarily.

The areas around the individual workstations are cluttered and concepts from Lean Manufacturing such as good housekeeping and minimizing waste are not currently in effect. Placement of cardboard boxes next to welding stations is a serious safety hazard in the workplace and compliance to OSHA regulations is being questioned. Operators have to walk distances to get to smaller parts, since only boxes of large parts are put line-side. At some workstations, operators have to bend down to pick parts from boxes; the ergonomics of these motions should be considered and improved on. There is currently no dedicated area allocated for repack operations.

Problems identified in the current area

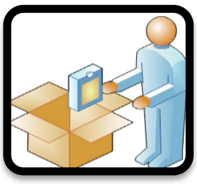


Cardboard boxes are placed next to welding stations

- a serious fire hazard
- no thermoplastic is present between work stations and boxes
- too many boxes are placed per part number - only one box per part is necessary

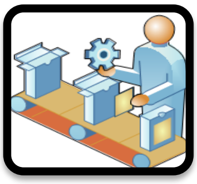
Poor housekeeping

- difficult for operator to move between boxes while repacking parts
- boxes are currently not placed on exact designated areas
- boxes are placed in the forklift aisle , creating a safety hazard



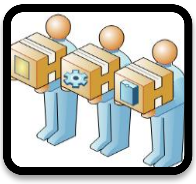
Poor repack methods are used

- parts are repacked from one box to another; boxes get worn out
- parts get damaged from poor repack methods
- some parts are not repacked on a FIFO basis



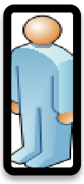
Not enough line-side tables

- only some parts are repacked properly to tables
- the current tables implemented are not standardized



Small parts have to be replenished a significant amount of times

- wastes time
- could be supplied directly to line-side in stead of being repacked
- unnecessary and redundant material handling should be avoided



The repack operators are not fully utilized

- these operators could be utilized in another area as well
- money is wasted as the operators are paid per hour, even for idle time
- as soon as the new repack area is implemented, the operators ahould be fully utilized

Figure 1: Problems identified

In the Solutions Methodology chapter of this document a detailed proposal is given to address and solve each of these problems.

Project Aim

The aim of the project is to analyse existing methods used at the X90 Body Shop of Nissan's plant in Rosslyn, and offer suggestions for improvement. This includes use of Work Measurement, Work Methods and Design, Production Engineering, Lean Manufacturing, Manufacturing Analysis and Control and Facilities Planning to solve existing problems.

An in-depth research on the Ergonomics and Safety of this specific production area has to be done as to ensure that existing work methods comply with safety regulations. Suggestions are made on ways to increase throughput, create a safer working environment and ensure optimal line feeding from the storage area to the manufacturing line where the body parts are welded together. The main topic that will be addressed is the congestion around the workstations. The current method of storing parts line-side will be investigated and a safe, closed area will be allocated for repack operations. Alternative proposals will be done for facility layouts to address problems mentioned.

The problems listed in the Problem Statement will be addressed individually to ensure that this manufacturing area produces a quality deliverable, on schedule with maximum employee satisfaction. Cost reduction and quality improvements are done by eliminating non-value-adding activities. These goals are reached through implementation of tools and techniques identified during the Literature Review.

Deliverables

The deliverables for this project is a Project Proposal, an Interim Report with a thorough Literature Review, a Draft Document, a Final Report which will be bound and become the property of the University of Pretoria, a poster and a presentation to the Industrial Engineering department.

A three-monthly progress report is presented to the Schnellecke and Nissan team, apart from the Interim, Draft Document and Final reports. The reports will include progress made in each part of the project, problems encountered during the time at Nissan (in form of a Risk Report), possible solutions, implementation procedures and any calculations made. The final report to Schnellecke and Nissan will entail a presentation as well as a copy of the final dissertation.

Note that not all data may be published, such as raw numbers, the Bill of Material, any photos and monetary amounts. In this case, proportions or percentages will be used as a substitute.

Deliverable	Date Expected
Project Proposal (Phase 1)	27 March 2012
Interim Report	8 May 2012
First 3-monthly Report to Schnellecke	End May
Presentation	During June Exam period
Second 3-monthly Report to Schnellecke	End August
First Draft of Document	5 September 2012
Final Document	17 October 2012
Third 3-monthly Report to Schnellecke	End October
Presentation and Poster	November

Figure 2: List of Deliverables and Dates

Project Scope

The scope of the project covers the Body Shop of the X90 automobile being manufactured at the Nissan Rosslyn plant. This includes the B90 and U90 models. The area that will be under investigation starts at the storage area next to this body shop, where parts are repacked onto trolleys. There are over 200 different types of parts being handled in this specific area. These parts are moved to the manufacturing line where it is stored line-side, and then welded together to form the frame of the vehicle. This process is also called Body-in-White assembly.

The project will include a problem definition, breaking the Body Shop area down into areas called workstations and using tools and techniques to optimize each workstation. For implementation purposes, only the three identified workstations will be selected for analysis to determine the best practise to be used with due regard to the operators' safety and job interest. This may be used as blueprint for every other work station in the X90 Body Shop.

Aspects that will be addressed include Lean Manufacturing, JIT line feeding, operator efficiency, reduction of materials handling and the quality of deliverables. Facility layouts will be drawn on AutoCAD for the current as well as each proposed design.

It is important to note that although most of the manufacturing line at Nissan is a mixed-model line, only the bodies of the Renault Sandero and Nissan NP200, called the X90 Project, are assembled in this area of body shop and is not considered a mixed-model system.

Current facility layout

AutoCAD is used as the main tool for drawing the current layout as well as proposed layouts during the solution development. The layout is drawn to scale and with accurate measurements, and future additions or changes can easily be done on the drawings.

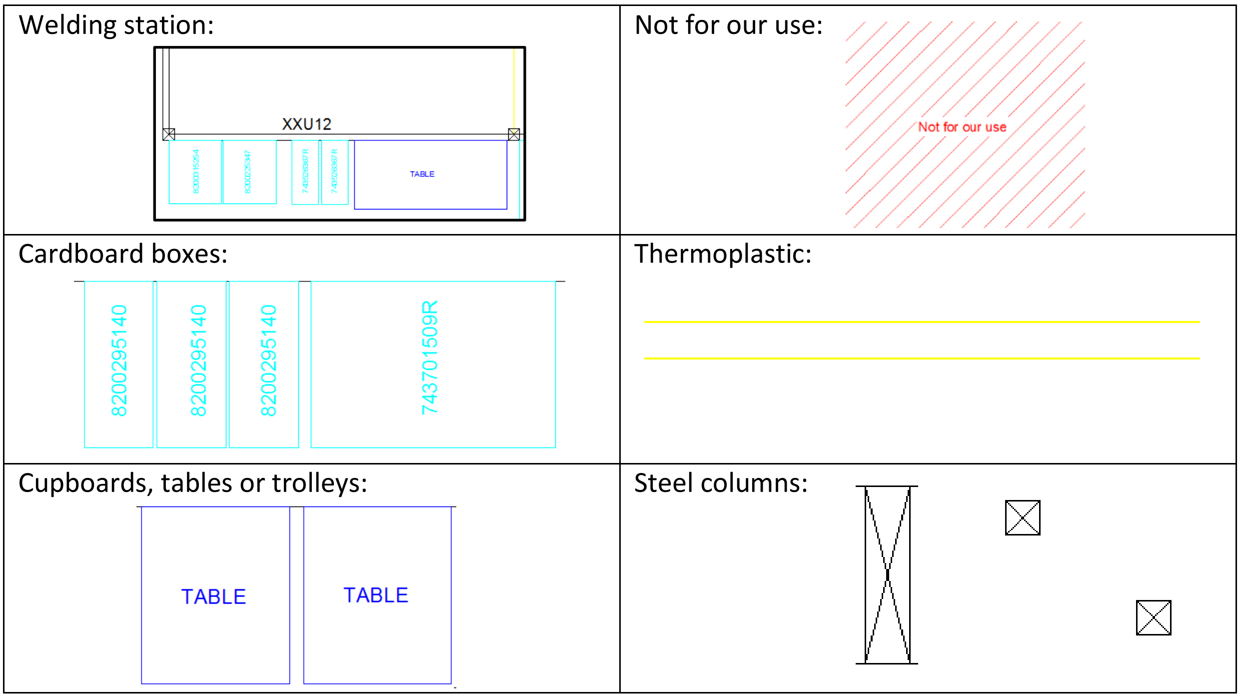


Figure 3: Colours used on AutoCAD drawings

Each yellow block demarcates a welding work station. The areas with red hatching are not for our use and not covered in this scope. Black is used for general demarcation of the work space. Black blocks with crosses, are steel columns and cannot be moved. The cardboard boxes are drawn in Cyan Blue, while cupboards, tables, trolleys and racks are Dark Blue.

The yellow double lines are thermoplastic as currently present in the area. Thermoplastic is thick sheeting hung from the roof where welding stations are placed next to marshalling areas or any area which might be in range of welding sparks and could cause a fire hazard.

The drawing below shows the X90 Body Shop area, with the red block as our main focus. If all suggestions made in this project are implemented successfully, the Nissan and Schnellecke team will consider implementing the same solution to the remaining area as well (though it is not in the scope of this project).

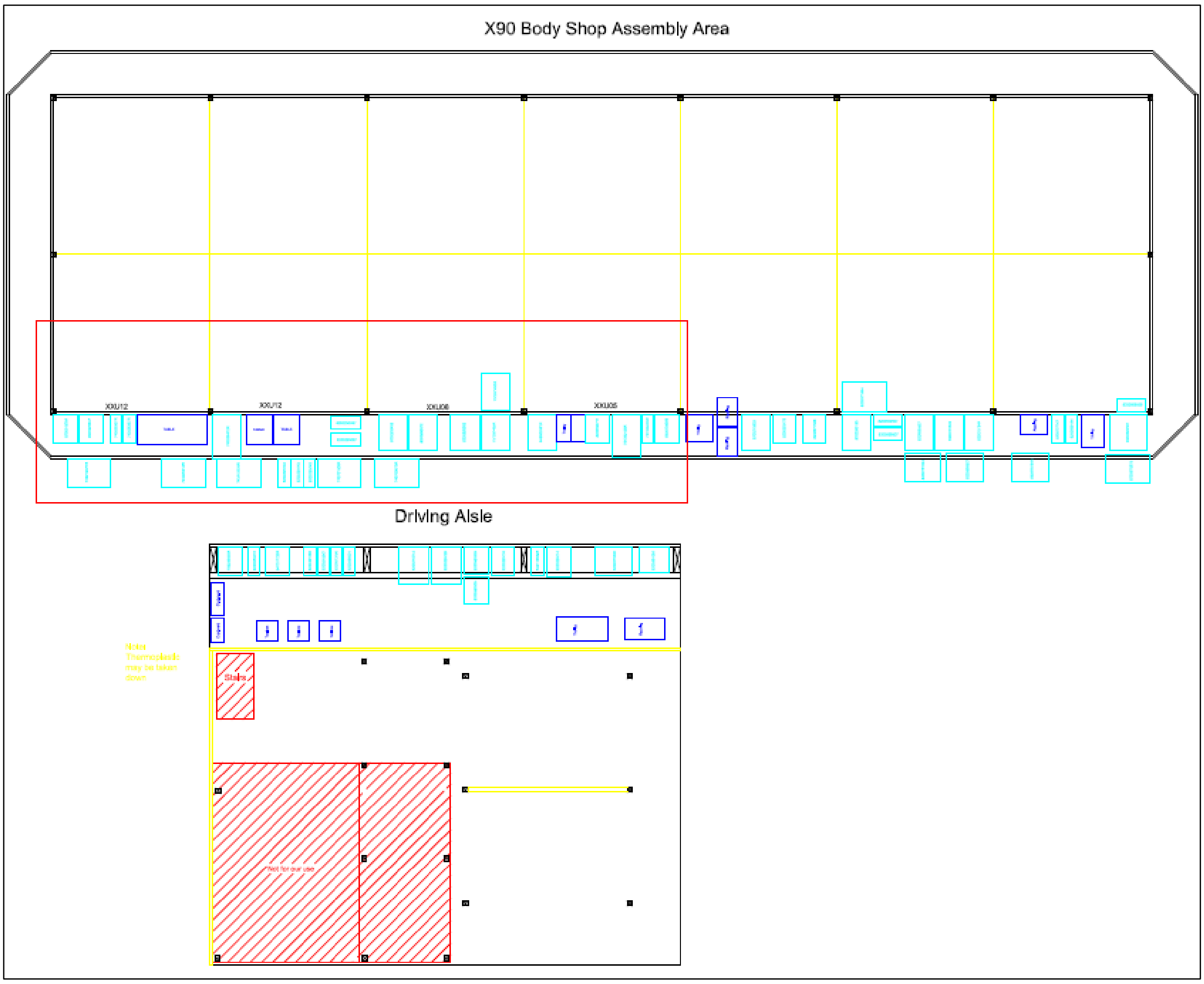


Figure 4: Current facility layout

Workstations under investigation

The workstations included in the scope are station XXU12, XXU06 and XXU05. These are fast-moving parts of various shapes and sizes.

Currently, boxes are placed line-side, sometimes two boxes per part number. The operator repacks parts from the full box to one that is almost empty. In the case where there is not enough space next to the line for a certain part number, this box is placed in the area across the forklift aisle (seen on the bottom of the drawing below). For these specific parts, the operator fetches a trolley and repacks parts from the box to the trolley, takes the trolley to the line, and repacks the part again to the line-side box/table/rack. Material is handled unnecessarily and easily damaged.

In the current layout, boxes are repacked directly next to the line – which means that there is very little distance moved during repack (minimizing material handling – something any floor manager would consider as positive). To be able to repack directly next to the line means that boxes are currently placed in the forklift aisle. This is unacceptable as it creates a hazard for material handling equipment, operators responsible for repacking, and any other operator moving in the aisle. The cardboard boxes next to the welding station pose safety issues.

These specific workstations have been chosen for investigation, as it poses the greatest safety risk in the entire X90 Body Shop at the moment and has poor or no housekeeping in place.

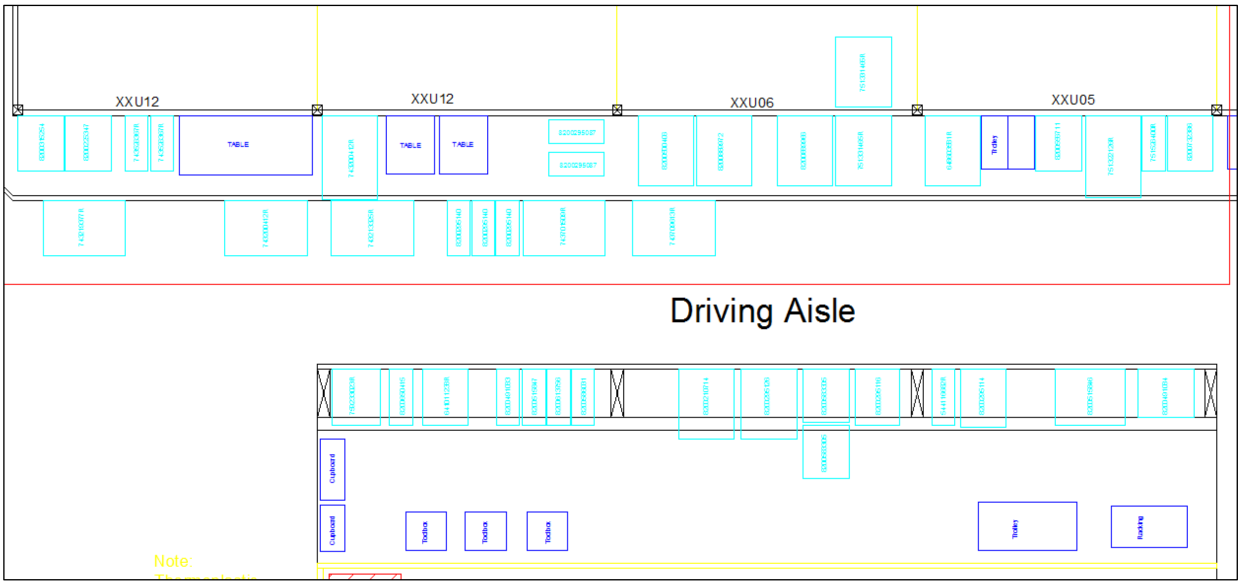


Figure 5: Workstations XXU12, XXU06 and XXU05 under investigation

Data Analysis

Job/Worksite Analysis Guide

A job/worksite Analysis Guide is a tool used to identify specific problems within an area, department or worksite in the first phases of the investigation. This Guide is conducted on the operator in the X90 Body Shop area that is responsible for repacking the line-side boxes when empty.

The questions relate to material handling and workplace activities. The repack operator, his tasks, the workplace and surrounding working environment are observed closely.

Job/Worksite Analysis Guide				
Job/Worksite: X90 Body Shop	Analyst: Lizet Engelbrecht		Date: July 2012	
Description: Analysis of repacker in the X90 Body Shop area				
Worker Factors				
Name: Matthews	Age: 22	Gender: M	Height: 1.6m	Weight: 65 kg
Motivation: Medium		Job satisfaction: Medium		
Education level: High School		Fitness level: Medium		
Personal protective equipment: *Safety Glasses* *Hard Hat* *Earplugs* *Safety Shoes* *Gloves* *Other*				
Task Factors		**Refer to**		
What happens? How do parts flow in/out? Repacker walks through area and replenishes almost-empty boxes at line-side		Flow Process Chart		
What kinds of motion are involved? Walking, lifting, grasping, placing		Principles of Motion Economy		
Are there any jigs/fixtures? Automation? Yes – Manual Packing Stillages				
Are any tools being used? NT cutter, crow bar		Tool Evaluation Checklist		
Is the workplace laid out well? Any long reaches? No, a lot of walking, long distances		Workstation Evaluation Checklist		
Are there awkward finger/wrist motions? No		CTD Risk Index		
Is there any lifting? Yes, larger and uncomfortable parts		NIOSH Lifting Analysis		
Is the worker fatigued? Physical workload? Some fatigue from walking and lifting		Work-rest allowances		
Is there any decision-making or mental workload? No				
What is the % workload? 130% for two workers, approx. 65% each		Time Studies		
Work Environment Factors		**Work Environment Checklist**		
Is illumination acceptable? Is there glare? Lighting is acceptable to requirements of task; welding operations require for safety glasses in area		IESNA Recommended Values		
Are noise levels acceptable? No, necessary to wear earplugs		OSHA Levels		
Is there heat stress? Some		WBGT		
Is there vibration? No		ISO Standards		
Administrative Factors				
Is there job rotation? Job enlargement? Yes, every half day repackers rotate between two jobs		Remarks:		
Is training or work hardening provided? Yes				

Bill of Material

The Bill of Material (BOM) is a document that contains the part number and description of the parts in workstations XXU12, XXU06 and XXU05 – the three workstations under investigation. It is important that the part numbers in the BOM correlates with the part numbers indicated on the AutoCAD drawings (as seen in the Problem Scope and Solutions Methodology).

This BOM has been obtained from the Nissan system for the duration of this project, but may not be published in the final document because of confidentiality requirements as agreed upon.

Flow Process Chart for packing operator

The Flow Process Chart is valuable in recording each task finished by the observed operator. The operator who does the repacking for the X90 Body Shop area was followed and observed for a full working day to establish the elements of each task. The Flow Process Charts is also an indicator of nonproduction hidden costs such as distances travelled, delays and temporary storage.

ASME standard symbols used:

o	Operation
⇒	Transport
D	Delay
□	Storage
∇	Inspection

The station number, part number and description of each element are given. A time study is done for each element, and the frequency that the specific part is repacked is given by the operator. An important factor to record is the distance a part is moved by the operator (where applicable). The estimated size of each part is indicated, and comments are made on whether the part is heavy and uncomfortable for the operator to handle.

Station	Part Number	Description of Elements	Symbol	Average Duration	Distance moved (m)	Frequency per Day	Comments
XXU06	743701509R	Open box [1]	o	10.00		3	Very big part, uncomfortable to handle. Repacked to table.
		Unload part to table [12]	o	5.67	0.5		
	8200500406	Open box [1]	o	6.00		4	Small part, repacked to hatrack-type trolley.
		Remove part from plastic [12]	o	5.00			
		Throw onto pile [12]	o	3.00			
		Load part to hatrack-type trolley [12]	o	3.00	1		
	8200295087	Open box [1]	o	15.00		2	Small part, repacked into line-side box.
		Overpack parts into line-side box [10]	o	3.83			
		Remove empty box [1]	o	15.00			
XXU12	743207103R	Open box [1]	o	30.00		2	Large part, repack to table.
		Pick part from box (6 at a time) [15]	o	9.00			
		Load part to table [15]	o	9.33			
	743219377R	Open box [1]	o	30.00		2	Large part, repack to table.
		Pick part from box [15]	o	7.17			
		Load part to table [15]	o	10.33			
XXU10	8200246300	Open box [1]	o	28.00		2	Small parts, loaded to bin. This bin is very heavy to carry.
		Pick part from box (5 at a time) [5]	o	3.00			
		Load part into small blue bin [5]	o	3.00	0.1		
		Load bin onto line-side rack [5]	o	6.50	4		
		Check content of all boxes [1]	∇	120.00		4	Visual check for replenishment.
		If almost empty, report to team leader [1]	o	120.00			
XXU04	752636616R	Open box in market area [1]	o	36.00		2	Medium Parts. Parts are currently located in market area (behind thermoplastic) far from the line.
		Pick part from box (4 at a time) [12]	o	7.67			
		Load part to bin-type trolley [12]	o	7.33			
		Move trolley to station [1]	⇒	20.00	20		
		Repack parts to centre of station [6]	o	24.00	5		
		Move empty trolley back to market area [1]	⇒	20.00	20		
Various	8200616942	Take flat trolley with smalls to station [1]	⇒	30.00	7	3	Small parts. Currently delivered to stations in postman-style.
	8200752209	Empty box into line-side rack [6]	o	60.00	4		
	Smalls						

XXU09	8200752207	Load box from flat trolley [8]	o	13.00		5	Small parts. Carried to centre of station and loaded into line-side racks. Not handled with care.
XXU04	8200587818	Carry box to centre of station [8]	⇒	18.67			
XXU02	8200570882	Unload from box to line-side rack [8]	o	28.33			
		Tea Break	D				
XXU04	8200515846	Open box in market area (across aisle) [1]	o	50.00		2	Medium parts. Parts are currently located in market area across aisle.
		Pick part from box (4 at a time) [12]	o	15.00			
		Load part to trolley [12]	o	11.33			
		Take trolley to station [1]	⇒	50.00	2		
XXU10	8200210714	Pick part from box (10 at a time) [11]	o	6.33		2	
		Load part to trolley [11]	o	7.33			
		Take trolley to station [1]	⇒	50.00	15		
		Unload part to middle of station [11]	o	36.00			
XXU06	8200491083	Open Box [1]	o	35.00		3	Small parts. Loaded to blue bin and taken to station.
		Pick part from box [10]	o	4.50			
		Load part to small blue bin [10]	o	3.83			
		Remove empty box [1]	o	22.00			
		Take blue bin to station [1]	⇒	35.00	7		
XXU09		Fetch tools to open case	o	120.00		2	Very large part, does not get repacked.
		Open case	o	180.00			
		Forklift replenishes line-side box	o	300.00			
		Remove plastic and throw away	o	120.00			
		Replace tools	o	120.00		2	
		Fetch random parts as requested by operators	o	180.00			
		Bathroom Break	D	540.00			
		Get forklift to replenish boxes	o	180.00		5	
		Take faulty parts produced to team leader	⇒	240.00		3	
XXU06	743709613R	Open box [1]	o	32.00			Second time this is repacked. Large part, loaded to line-side table.
		Pick part from box	o	4.33			
		Load part to table	o	6.17	2		
XXU04	8200732386	Pick part from box (10 at a time) [9]	o	9.33		1	Medium parts. Not handled with care.
		Tip parts out from box to line-side rack [9]	o	15.00			

XXU06	8200500406	Open box [1]	o	20.00		4	Packing operator's cycle starts from the beginning.
		Pick parts and remove plastic	o	6.33			
		Throw onto pile	o	1.00			
		Load part to hatrack-type trolley	o	2.33			
		Idle Time	D				
	Smalls	Check boxes on flat trolley	o	30.00			Small parts on flat trolley.
		Take trolley to station	⇒	30.00	20		
		Take box to centre of station	⇒	5.00			
		Unload box to line-side rack	o	30.00			
XXU05	8200295114	Open box and plastic [1]	o	33.00		2	Small parts.
		Repack almost empty box to full box [1]	o	180.00			
		Remove empty box [1]	o	25.00			
XXU09	8200752207	Move flat trolley to station	⇒	20.00	5		Small parts. Loaded many times a day, very redundant.
XXU08	8200752209	Unload box to middle of station	o	18.00			
		Open box and tip out into line-side rack	o	40.00			
Various	Screws	Hand out packs of screws to operators	o	60.00		8	
XXU12	743100241R	Open box	o	100.00			Second time today. Large parts. Loaded to line-side table.
		Pick part from box (4 at a time)	o	4.67			
		Load part to table	o	5.33	0.1		
		Get forklift to replenish boxes	o	180.00			
XXU12	8200225347	Open box	o	35.00		2	Medium parts. Repacked to line-side box.
		Pick part from box (7 at a time) [15]	o	8.67			
		Load part to line-side box [15]	o	12.00			
XXU04	751322126R	Open box [1]	o	35.00		2	Medium parts. Repacked to line-side box.
		Pick part from box (2 at a time) [16]	o	5.50			
		Load part to line-side box [16]	o	5.33			
	Smalls	Fetch random parts as requested by operators	o	600.00			System only orders 2 boxes at a time. Very redundant.
	8200569525						
		Lunch Break.	D				
	Screws	Hand out packs of screws to operators	o				
		Idle Time	D				
XXU10	8200210701	Repack to line-side box	o	120.00		2	Other side of area (N/A to study)
XXU09	8200569507	Open box and remove plastic [1]	o	60.00		2	

	8200570882	Fetch flat trolley	⇒	15.00	10		
		Unload box from trolley and open box	o	11.67		6	Small parts.
		Repack parts to line-side rack	o	16.67			
XXU08		Move trolley to station	⇒	30.00	10		
XXU03		Open box	o	12.00			
		Repack boxes to line-side rack	o	8.00			Small parts. Flat trolley.
		Move trolley back to market area	⇒	20.00			
XXU08	8200589521	Open box [1]	o	35.00			
		Pick parts from box (8 at a time) [12]	o	10.83		2	Medium parts. Other side of area (N/A to study)
		Load parts to line-side rack [12]	o	17.17			
		Remove box [1]	o	35.00			
XXU06	743709613R	Pick part from box. [10]	o	13.00		1	Large parts.
		Load parts to trolley. [10]	o	10.33			

The Flow Process Chart indicates that certain parts are heavy and uncomfortable for the operator to handle. These parts require specific attention during solution development. Parts being moved more than 3m should also be considered as elements that have a significant effect on the operator's time utilization.

It is clear that the repacking of small parts have a high frequency, is redundant and it is suggested that these parts are to be supplied directly to the line by the supplier (and not handled by the operator). This will reduce material handling on these parts, and reduce wasted time by the operator.

Time Studies and Operator Utilization of current processes

A time study was conducted for each element of each task that the repack operator is responsible for in one work day. These elements are combined to conduct an overall time study. The final goal of the time study is to determine the percentage loading of a single operator.

The X90 body shop area under investigation currently uses two operators responsible for all the repack activities. These operators have exactly the same flow of processes throughout the day – thus a combined time study is conducted, and the percentage loading is divided by two afterwards to give an indication of how efficiently these operators use their time throughout the day.

A percentage workload of 80%-90% is expected from an operator who does hard labour. Note that a % allowance for fatigue, restroom breaks and idle time is included in the time study.

The conducted time study indicates the following:

- The percentage workload is calculated at 130%, thus about 65% per operator. This is not acceptable, and indicates that money is wasted on man-hours, as the operators could be better utilized. This will not be a problem once the new layout and repack process (as seen in the solution development) is implemented. Since the operator will now have to move from the repack area to the line, operators will be utilized fully.
- A lot of time is unnecessarily spent on repacking small parts. It is suggested that small parts (such as screws and bolts, or any part that can easily be carried by hand) be delivered straight to line-side pigeon-hole type racks by the suppliers, and thus not repacked by the operators.

Time studies are included in Appendix B.

CHAPTER 2: LITERATURE REVIEW

According to Niebel's Methods, Standards and Work Design (Freivalds, 2009), an increase in productivity is one of the main ways a business can attempt to expand and increase its profitability. According to this textbook, a few of the essential tools that result in increased productivity, include methods engineering, time study standards and work design. These are only some of the aspects that will be covered in this literature review. Freivalds defines methods engineering as a practise for increasing the production per unit time or decreasing the cost per unit output.

This literature review addresses various fields of interest in industrial engineering, including Lean Manufacturing, line-side storage, Ergonomics, Materials Handling and Facility Planning.

Internet Journals, discussions and personal observations

What is Lean Manufacturing?

According to a journal on Lean Indicators and Manufacturing Strategies (Sanchez & Perez, 2001), the attention surrounding lean production is based on indications that it improves the company's competitiveness by increasing productivity, while lowering lead time costs and refining the standard of quality delivered.

A brief history of this concept is given in the article The Benefits of Lean Manufacturing (Melton T. , 2005). Toyota is accountable for coining the phrase 'lean logistics' in the 1940s in Japan. The Toyota Manufacturing System was grounded on the need to manufacture automobiles in a constant on-going flow which did not rely on lengthy production runs to be entirely efficient; Toyota recognized that only a small portion of the overall production time and effort actually added some value to the final customer, the rest of the activities is considered to be wasteful.

Meanwhile, the Western world was doing the opposite of this practise; concepts such as Materials Resource Planning (MRP) and other systems based on intricate computerized methods were being developed. Henry Ford's philosophy of bulk-sized assembly of standardized products with little product changeovers was also being followed. Henry Ford based his viewpoint on mass production.

Taiichi Ohno became the father of the Lean Manufacturing methodology in the Toyota Production system in the 1940s to 1980s. The five main tools within this 'lean' ideology include:

- 5 S's: a method of visual housekeeping which delegated control to the shop floor.
- Visual control: a way of determining performance at the 'shop floor' which was visual and owned by the group of operators.
- Kanban: a visual signalling system to ensure flow by letting the product be pulled through the production line as by the end-customer requirements.
- Poka yoke: a tool for 'error-proofing' the manufacturing process.
- Single minute exchange of dies (SMED): a method to reduce length of changeovers.

During the research of this specific project, however, only some aspects of Lean Manufacturing will be covered, such as waste, value stream mapping and flow of products. Lean is a concept that should be drawn across an entire supply chain, but we are only focusing on one part of the SC – the

X90 body shop. The focus will be on elimination of zero-value activities. This is the elimination of everything that does not add value to the product in this specific area of manufacturing.

An article in the International Journal of Physical Distribution & Logistics Management (Jones, Hines, & Rich, 1997) discussed the seven common forms of waste, as defined by Taiichi Ohno:

Waste is events and activities that are non-value-adding; it only adds to the expenses of production. Examples of waste include the percentage of products that are not yet ordered by the customer; time spent waiting for parts to arrive at a work station; rectification of errors; superfluous processing; unnecessary movement of material; unnecessary transport; and additional stock at hand. It is common to find that in a manufacturing plant less that 5 % of activities actually add value, 35 % are non-value-adding activities that are absolutely necessary and cannot be reduced and 60 % are completely non-value-adding. It is fairly easy to identify the actions that add value, but it is much more difficult to identify all the waste that surrounds these actions. A huge productivity improvement lies in eliminating the 60% of non-value-adding activities.

Some of the key elements from Toyota's tool kit are relevant to this project:

- Organize the manufacturing operations so the product flows directly from one work station to the next without interruptions. Set-up time is shortened to deliver each product daily or weekly. Implementing preventative maintenance, occurrence of breakdowns is minimized.
- Guarantee consistent performance by standardizing the optimum cycle for the work at each station. Standardization of the repack process in the X90 Body Shop should be considered.
- Ensure that operators stop immediately as they detect errors, so that it is not passed on to the next work station. This makes it possible to detect rogue orders against historic data.
- Manage the progress of the production line and eliminate irregularities using simple graphic control devices.
- Teach operators to log the irregularities found during production; this enables the manager to conduct root cause elimination and prevent this from happening again. It also helps remove waste from the process flow.

One of the Lean Manufacturing concepts is "Value Stream Mapping". Under this concept, we will use Process Activity Mapping, which consists of the following five stages:

1. The study of the flow of processes for the repack operation;
2. The identification of non-value-adding activities in the X90 area;
3. Deliberation of whether the current method of repacking parts can be rearranged into a more efficient sequence of processes;
4. Consideration of an improved flow pattern; possibly changing the flow layout or transportation routes using a tool such as AutoCAD;
5. Asking whether all actions that are being done are truly essential.

The 7 'zero' ultimate objects	
	Speediness and maintenance of production
	Guarantee of lean quality and automation
	Flexible production system
	Balanced production and synchronization
	IE work research on the spot
	Production plan and logistic system
	The research and development system of products

Figure 6: The Ultimate Object of Lean Manufacturing. Source: (Wu, 2009)

#	STEP	FLOW	AREA	DIST (M)	TIME (MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
1	RAW MATERIAL	S	RESERVOIR				O	T	I	S	D	RESERVOIR ADDITIVES
2	KITTING	O	WAREHOUSE	10	5	1	O	T	I	S	D	
3	DELIVERY TO LIFT	T		120		1	O	T	I	S	D	
4	OFFLOAD FROM LIFT	T			0.5	1/2	O	T	I	S	D	
5	WAIT FOR MIX	D	MIX AREA		20		O	T	I	S	D	
6	PUT IN CRADLE	T		20	2	1/2	O	T	I	S	D	
7	PIERCE/POUR	O	MIX AREA 12		0.5		O	T	I	S	D	
8	MIX (BLOWERS)	O			20	1/2	O	T	I	S	D	BASE MATERIALBLOW & ADDITIVES
9	TEST #1	I			30	1+1	O	T	I	S	D	SAMPLE/TEST
10	PUMP TO STORAGE TANK	T	STORE TANK	100		1	O	T	I	S	D	DEDICATED RESERVOIR
11	MIX IN STORAGE TANK	O	STORE TANK		10	1	O	T	I	S		
12	IR REST	1			10	1+1	O	T	I	S	D	STAMP & APPROVE
13	AWAIT FILLING	D			15		O	T	I	S	D	LONGER IF SCREEN LATE
14	TO FILLER HEAD	T		20	0.1	1	O	T	I	S	D	
15	FILL/TOP/TIGHTEN	O	FILLER HEAD		1	1+1	O	T	I	S	D	1 UNIT
16	STACK	T	PALLET	5	0.1	1	O	T	I	S	D	1 UNIT
17	DELAY TO FILL PALLET	D			30		O	T	I	S	D	
18	STRAP PALLET	O			2		O	T	I	S	D	
19	TRANSFER TO STORE	T		80	2	1	O	T	I	S	D	
20	AWAIT TRUCK	D	STORE		540		O	T	I	S	D	BATCH 360/ QUEUE 180
21	PICK/MOVE BY FORK LIFT	T		90	3	1	O	T	I	S	D	FORK LIFT
22	WAIT TO FILL FULL LOAD	D	LORRY		30	1+1	O	T	I	S	D	1 OPERATOR 1 HAULIER
23	AWAIT SHIPMENT	D	LORRY		60	1	O	T	I	S	D	1 HAULIER
	TOTAL		23 STEPS	443	781.2	25	6	8	2	1	6	
	OPERATORS				38.5	8						
	% VALUE ADDING				4.93%	32%						

Figure 7: Process Mapping – an industry example

Another technique that could be borrowed from Lean Thinking is asking the questions: Why does an activity occur, Who does the activity, on What machine is this activity done, Where, When and How. This is called the 5WlH. The basis of this concept is to eliminate unnecessary activities, simplify others, combine others and identify ways to change the sequence in order to reduce any waste.

The benefits of Lean Manufacturing

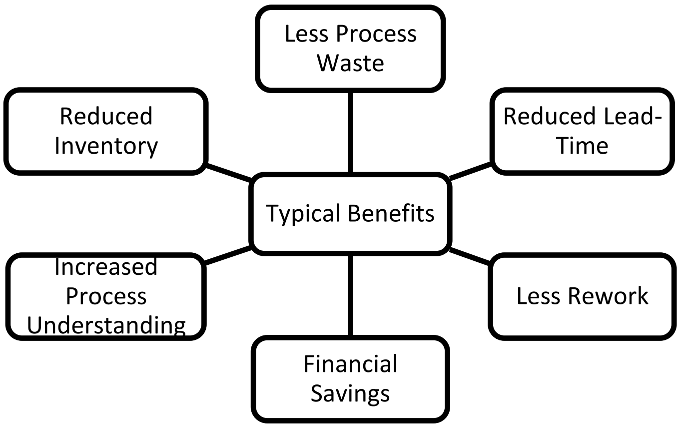


Figure 8: The Benefits of Lean Manufacturing. Source: (Melton, 2005)

In the same journal cited previously (Melton T. , 2005), the benefits of a manufacturing line being "lean" is discussed clearly. According to this journal, the benefits seen within the automotive industry (see Figure 4), such as Nissan, include:

- reduced inventories for the manufacturing companies;
- reduced lead times for the end-customer;
- overall better knowledge management;
- more robust practises (minimized errors and consequently there will be less rework).

These benefits make the "lean" methodology a real and physical concept, particularly for the manufacturing industry. Over the entire supply chain Lean Manufacturing has now been applied. There are multiple documented case studies of the application of 'lean thinking' to business processes such as project management, construction and design. Lean Manufacturing should be applied to all facets of the supply chain.

The application of this ideology in the industry is not without problems. The two main complications are based on human assumption: the perceived lack of palpable benefits and managers' opinion that their industry processes are already efficient as it is. Both assumptions can be challenged (Melton, 2004):

- There are many concrete benefits related to supply chains that have implemented Lean thinking. A lean process will not be as slow as before, e.g. the response rate to a request for the business process will be quicker, which naturally leads to substantial financial benefits for this business.
- The assumption that a certain process is already effective enough in its current state is usually an illusion. The implementation of Lean Manufacturing forces companies to review the entire supply chain in which the business process functions, and this usually reveals bottlenecks, hold-ups and areas that are not as efficient as can be.

Nissan is not under the illusion that the assembly line in the body shop is efficient in its current state. Through discussions with industrial engineers and floor managers, it is clear that Lean Manufacturing is a notion that could (and should) be effectively implemented in this part of the plant.

“Value” with regards to Lean Manufacturing

The supply chain is a vehicle for delivering the product (of certain value or worth) to the end-customer. The lean concept is applicable to Manufacturing Businesses and specified processes in that industry. Waste can be eliminated from most steps of the production line: from the development and design of the initial product, all the way down to the planning of the facility layout.

However, to truly apply the concept of lean thinking, all these elements have to be interconnected within a robust supply chain and the flow of value has to be ensured. This leads to what is now called a ‘lean enterprise’ (Lean Enterprise Research Centre, 2004).

Manufacturing processes can be greatly improved by eliminating waste. The key is to:

1. Realize the difference between waste and value in the supply chain;
2. Expand our base knowledge management;
3. See that sustainable development calls for the cooperation of the process operators as well as the business management, and therefore a philosophy of on-going improvement toward perfection.

Value can be defined as the worth of something compared to the price paid or asked for it. Different customers, however, might view value differently (see figure 9 below).

Defining “value” from the customer’s point of view and identifying this value is the first step to implementation of lean thinking in the Nissan X90 Body Shop. Without a clear understanding of what meaning ‘value’ holds for the customer, we cannot move forward. Various examples exist of what is meant by “value proposition”; a buyer purchasing a washing machine may value the ability to wash their clothes at home; while others’ value may be based on the price or some special features that the product offer. The manufacturer is challenged to develop a product portfolio based on these value propositions.

Figure 9 gives instances of such value propositions as related to specific customer groups, their product portfolio and potential capabilities. For customer A, development of the process they hand over to the toll manufacturer is a value added activity; for customer B this is considered to be waste.

	Customer Type	Value Proposition	Manufacturer Type
A	Major pharmaceutical manufacturer of drug products	Robust process and product development at fast track speed ensuring regulatory compliance	Toll manufacturer of pharmaceutical intermediates
B	Other manufacturer in a low cost base industry	Correct specification, low cost and delivered on time in the volumes specified	Bulk chemicals manufacturer
C	The patient (via the companies who distribute the drugs)	High quality, safe drugs that ‘work’ at an appropriate price	Major pharmaceutical manufacturer of drug products

Figure 9: Value propositions for different customer types. Source: (Melton, 2005)

"Waste" with regards to Lean Manufacturing

Waste has already been defined and discussed in this Literature Study. An additional definition is cited from a journal also viewed earlier (Melton, 2005). Any task in a production process that adds no value or worth to the end-customer is considered waste, or "Muda", as the Japanese calls it. In some cases, the waste adds value to the company or is a necessary part of the process and thus cannot be eliminated.

All waste that is not considered "necessary" to the process, should be eliminated as far as possible. Figure 10 lists the seven main types of waste; each of which is present in the body shop area under investigation in this project. At first, waste can be recognized with ease in the processes along the body shop's supply chain and early alterations or modifications can lead to vast savings for Nissan. As the processes constantly improve, the waste reduction will be more incremental as the company strives for a waste-free production line.

Continuous improvement is one of the main principles of implementing lean logistics. The data in Figure 11 shows only a small part of the amount and types of waste that could be found in the overall supply chains. It is of utmost importance to identify the root cause (the 'real' waste) in order to eliminate all its repercussions.

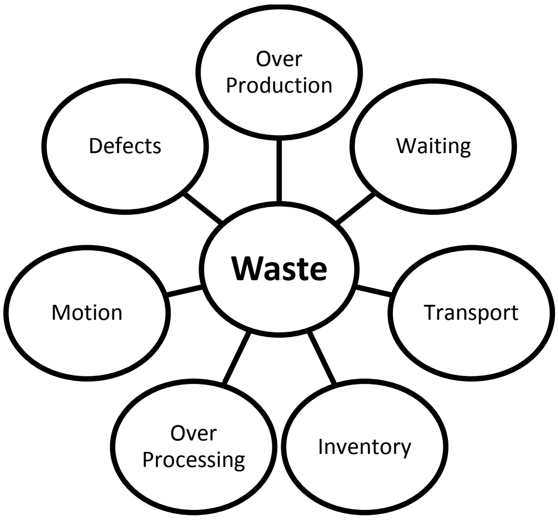


Figure 10: Seven types of Waste. Source: (Melton, 2005)

Walking through the X90 body shop at Nissan, it is clear that these forms of waste are present throughout the assembly line. Some examples include:

- An overproduction of parts
- Unnecessary transport of material
- Excessive motions during picking of parts and assembly of products
- Presence of defects on parts because of poor quality in materials handling
- Some parts are over-packed into boxes that stand line-side for weeks on end. The box deteriorates, and the parts are thrown on top of one another, increasing the chances of defectives in the batch.

Type of waste	Description	Within the process industry	Example symptom
1. Over production	• Product made for no specific customer • Development of a product, a process or a manufacturing facility for no additional value	• Large campaign—large batch and continuous large-scale manufacturing processes • Development of alternative process routes which are not used or the development of processes which do not support the bottleneck • Redesign of parts of the manufacturing facility which are 'standard', e.g., reactors	• The extent of warehouse space needed and used • Development and production organization imbalance • An ever changing process (tweaked) • Large engineering costs/time associated with facility modifications
2. Waiting	• As people, equipment or product waits to be processed it is not adding any value to the customer	• Storage tanks acting as product buffers in the manufacturing process—waiting to be processed by the next step • Intermediate product which cannot leave site until lab tests and paperwork are complete	• The large amount of 'work in progress' held up in the manufacturing process—often seen on the balance sheet and as 'piles of inventory' around the site
3. Transport	• Moving the product to several locations • Whilst the product is in motion it is not being processed and therefore not adding value to the customer	• Raw materials are made in several locations and transported to one site where a bulk intermediate is made. This is then transported to another site for final product processing • Packaging for customer use may be at a separate site	• Movement of pallets of intermediate product around a site or between sites • Large warehousing and continual movement of intermediate material on and off site rather than final product
4. Inventory	• Storage of products, intermediates, raw materials, and so on, all costs money	• Economically large batches of raw material are purchased for large campaigns and sit in the warehouse for extended periods • Queued batches of intermediate material may require specific warehousing or segregation especially if the lab analysis is yet to be completed or confirmed	• Large buffer stocks within a manufacturing facility and also large warehousing on the site; financially seen as a huge use of working capital
5. Over processing	• When a particular process step does not add value to the product	• A cautious approach to the design of unit operations can extend processing times and can include steps, such as hold or testing, which add no value • The duplication of any steps related to the supply chain process, e.g., sampling, checking	• The reaction stage is typically complete within minutes yet we continue to process for hours or days • We have in process controls which never show a failure • The delay of documents to accompany finished product
6. Motion	• The excessive movement of the people who operate the manufacturing facility is wasteful. Whilst they are in motion they cannot support the processing of the product • Excessive movement of data, decisions and information	• People transporting samples or documentation • People required to move work in progress to and from the warehouse • People required to meet with other people to confirm key decisions in the supply chain process • People entering key data into MRP systems	• Large teams of operators moving to and from the manufacturing unit but less activity actually within the unit • Data entry being seen as a problem within MRP systems
7. Defects	• Errors during the process—either requiring re-work or additional work	• Material out of specification; batch documentation incomplete • Data and data entry errors • General miscommunication	• Missed or late orders • Excessive overtime • Increased operating costs

Figure 11: Seven types of Waste

"Flow" with regards to Lean Manufacturing

One of the concepts of Lean Manufacturing that is hardest to understand is "Flow" (Melton T. , 2005). It is the notion which most clearly contradicts with large quantity manufacturing systems (Henry Ford's philosophy); comparing a single flow against batch and queue processes. The business's working capital is consumed by large warehouses which store huge amounts of inventory. The size of these warehouses is caused by a lack of flow in our supply chain. To understand the concept of flow the term "value stream" can be defined as the relation of tasks which finally produces value to an end-customer. A value stream crosses all practical and organizational boundaries.

Figure 12 demonstrates an example of a typical value stream for a toll manufacturer. The value stream only shows the primary stages of value being added and the main teams involved (and not the supporting activities). Flow is concerned with processes, people and culture.

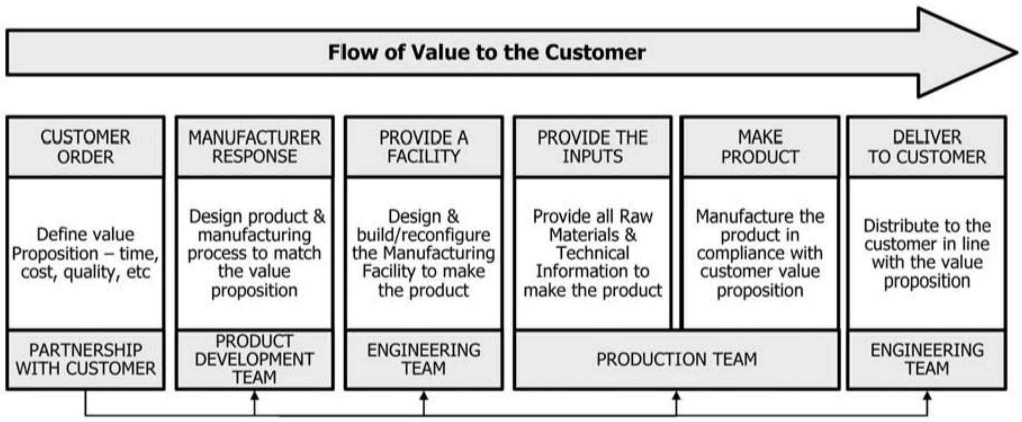


Figure 12: A Simple Value Stream. Source: (Melton, 2005)

In The Goal (Goldratt & Cox, 1993), the concepts around a value stream are discussed. The key reasons for an absence of flow (or constraints in the supply chain) are also mentioned. Goldratt and Cox developed some guidance to control a manufacturing line in how it is supposed to be managed. This guidance is formed around the following concepts:

1. Throughput: the degree to which the supply chain generates money through sales (actual sales should be used, not actual production; if a product is produced, but not sold, it is not considered throughput). The lean philosophy of manufacturing only when the customer 'pulls' is supported in this idea.
2. Inventory: the monetary amount that the system used for procuring products which it has the intention to sell.
3. Operational expense: the monetary amount spent by the system in order to convert inventory into throughput.

The aim of that production operation is defined as ensuring a higher throughput while lowering both operating expense and inventory. It is stated that any improvement in the system must be tested against this idea:

- Will this improvement lead to:
  - An increase in the sales of products? (Has Throughput increased?)
  - A reduction in raw materials and overtime? (Is Operating Expense reduced?)
  - A reduction in the plant's over-all inventory?

The final notion introduced in The Goal is that of the bottleneck - the throughput of the entire process is determined by this single step. This also supports the philosophy of lean production through 'pull' which communicates to operators that it is acceptable to halt production (when there is no 'pull' from the end-customer).

'A value stream perspective means improving the whole supply chains, not just improving some the parts' (Rother & Shook, 1999). It also suggests that we need to function as a supply chain, and not necessarily as individual production units.

How to start thinking in terms of "Lean Manufacturing"

A data-rational, organized method is necessary if the main ideologies of value, flow and waste are to be thoroughly applied through the process supply chain. The process of implementing Lean Manufacturing (Figure 13) is shortly described:

- Document the existing process performance – how is it done at the moment.
- Outline value and then eliminate waste (non-value-adding activities).
- Identify unwanted effects. Find their root cause to be able to eliminate the actual problem.
- Solve this problem by re-designing the process.
- Determine whether value flow is now sufficient to the end-customer of the specific process.

Many methods and practises exist to support each phase of the process described above (that support application of the philosophies). Managers that have been involved in performance improvements are surprised that the ideologies of Lean Manufacturing can be put into action using methods that are well-known to them and that they have used before. The difference is the fact that they are used to guarantee that:

- The process line delivers value to the end-customers;
- Every task that is non-value-adding is eliminated as far as possible;
- The supply chain now flows within a 'lean' and robust supply chain.

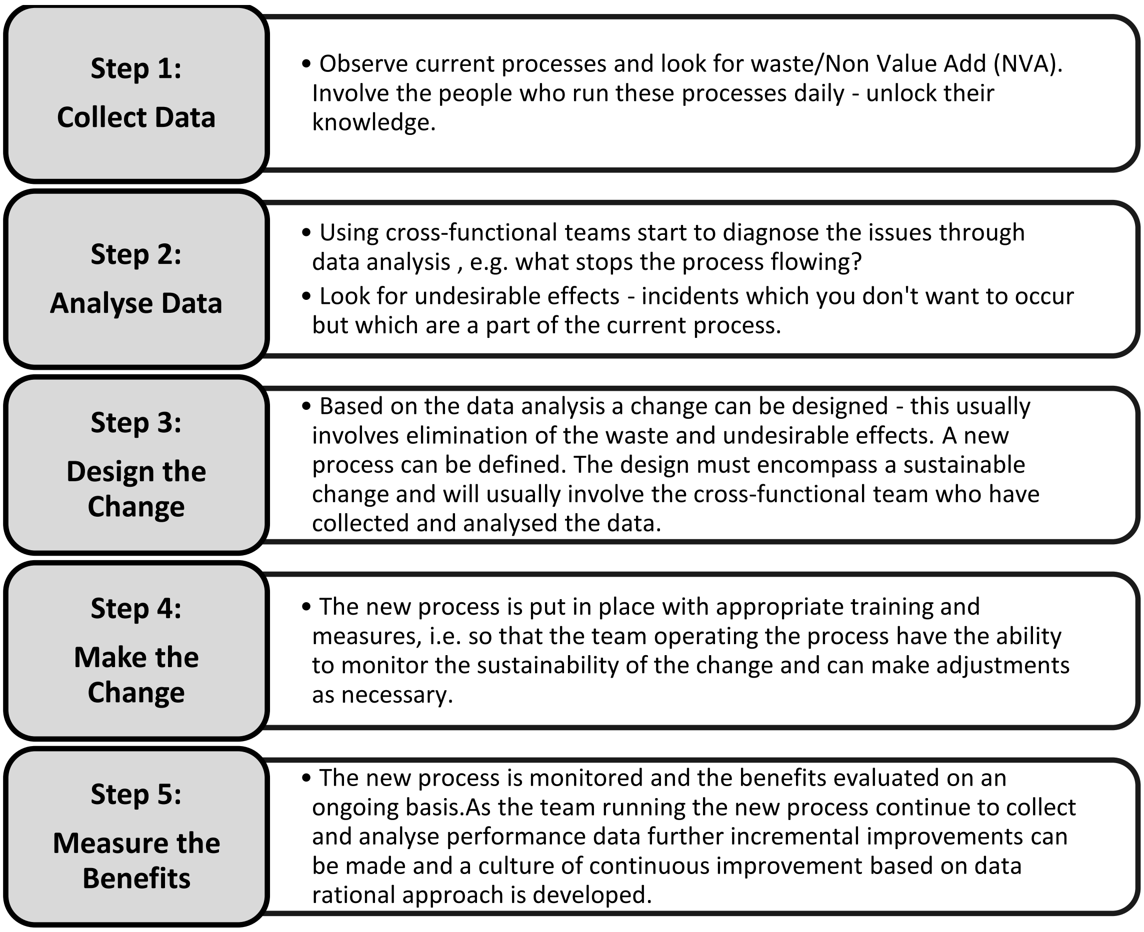


Figure 13: How to implement Lean Manufacturing. Source: (Melton, 2005)

Line side storage and packaging

In a journal article on the impact of materials feeding design (Wänström & Medbo, 2008), it is explained that the design of component racks and choice of packaging types have a significant effect on the performance of the assembly line. A component rack that is mobile and fairly easy to rearrange, together with free space, makes the handling of new products or alterations of products much easier.

Limitations that may be encountered in this area of research consist of space restrictions and working conditions at the individual workstations. Component racks are defined as a facility with which materials are made available and held (or temporarily stored) at assembly work stations, e.g. a rack, stand, fixture, shelf or trolley. A component rack could be a permanently bolted EUR-pallet rack placed next to the assembly line. The racks can be furnished with shelves and flow racks for various shapes and sizes of containers. Gravity flow racks are only used for smaller parts.

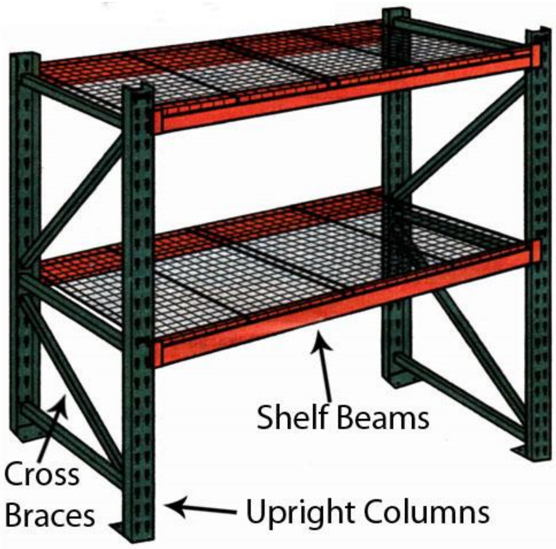


Figure 14: Example of racking

The current practise at Nissan's body shop is to place the pallets with the original cardboard box right next to the workstation. In certain areas, over-packing is done; parts are manually moved from the current container to a container that has been standing line-side for a period of time. These line-side containers are often damaged, and parts are not replenished in a FIFO sequence. Parts at the bottom of the box could be old and damaged.

Where large parts such as door panels are handled, the parts are repacked onto basic line-side tables. Provision is made for certain parts that are awkwardly shaped and difficult to handle, but this is the exception.

Designs will be done for line-side tables, racks and trolleys in the Solution Development chapter. Each piece of material handling equipment will be standardized and designed according to ergonomic standards. Line-side tables will be implemented for all part numbers – not exclusively large parts. Suggestions could be made on the provision of small parts to be delivered directly to the line. For these small parts, pigeon-hole type racks with gravity chutes may be used.

The Body Shop

Within the car body shop of an automotive plant such as Nissan, the body-in-white is assembled from pre-formed pieces of metal (Spieckermann, Gutenshwager, Holger, & Vos, 2000). At the Nissan plant, these pieces of metal are produced and received locally. In the body assembly shop, up to one hundred welding machines and various other equipment are needed to complete the body-in-white before it is transported to the next phase of the assembly process. Manufacturers have to design a new body shop for almost each new model to be manufactured in the plant. A typical example of assembly flow is demonstrated in Figure 15.

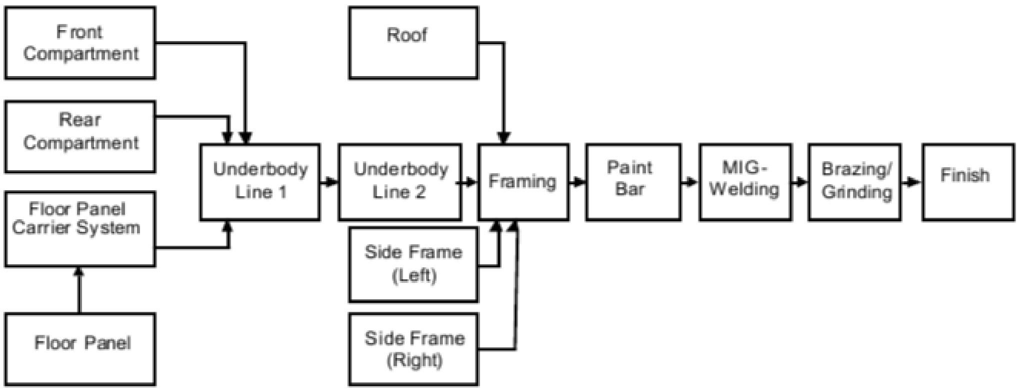


Figure 15: Conceptual Design of a Body Shop

Ergonomics in the work station

Work-in-process (WIP) includes all the assembly materials in the assembly line (Cao & Zhao, 2011). Normally, as in the Nissan Body Shop, there is one assembly done per workstation. Buffer inventory may be stored at the workstation for multiple assemblies. Making material available to the line and transfer of material are closely related to facility space requirements, material distribution systems, and line operation strategies.

The design of manual work was introduced by Gilbreths through motion study and the principles of motion economy (Freivalds, 2009). The principles of motion study have been broken down into three basic categories:

1. The use of the human body
2. Arrangements and conditions of the workplace
3. Design of tools and equipment at the work station

These principles form the scientific basis for ergonomics and work design. Some principles of motion economy that is applicable to the Nissan operator include:

- Achieve maximum muscle strength at midrange of motion
- Achieve maximum muscle strength with slow movements
- Use momentum to assist the operator wherever possible
- Design the jobs to optimize human strength capability
- Use large muscles for tasks requiring strength
- Design tasks so that most operators are able to do them

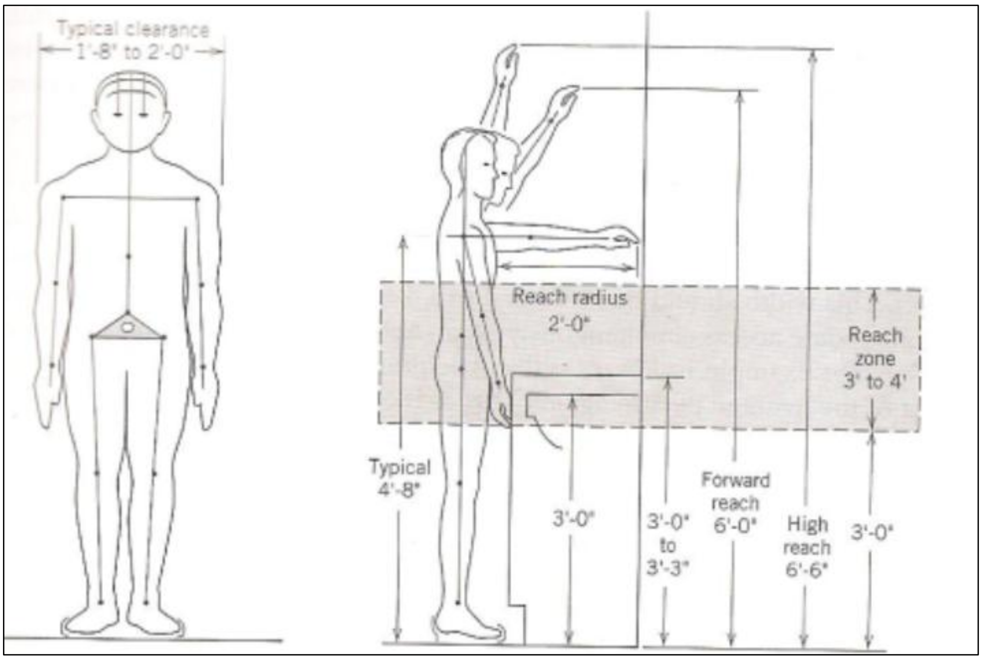


Figure 16: Anthropomorphic clearance and reach requirements in standing position. Source: (Tompkins, 2010)

Application of these ergonomic principles is used in the design of all material handling equipment as well as the proposed repack process during solution development for the X90 Body Shop.

Material Handling

Material handling includes motion, time, place, quantity and space constraints. According to Niebel's Methods, Standards and Work Design (Freivalds, 2009), between 30 and 85% of the cost of getting the product to the end-customer is related to material handling. According to this textbook, the best handled part is the one that has been least manually handled.

Four key points that should be considered for reducing the time spent in material being handled by the Nissan operator while picking, loading or moving parts:

1. Reduce any time spent in picking up material
2. Make better use of current handling facilities or techniques
3. Handle all material with greater care to reduce damage
4. Consider the application of bar coding for inventory

Even though the area of transportation may offer great opportunity for savings, work station positioning of material should also be considered. Reducing the time spent in picking up material minimizes tiring of the operator, costly manual handling at the machine or the work station. The job can be done faster with less fatigue and greater safety. Using mechanical equipment reduces labour cost, alleviates fatigue and improves production rates.

Equipment standardization is important, and the application of this principle is seen in the proposed designs of the trolley, rack and line-side tables later in this document. Almost 40% of plant accidents happen during material handling operations. Safe operating practices, good lighting and good housekeeping are also essential.

Facility Planning

In today's competitive marketplace, facility planning is used as a strategy, not just a science. Modern day facility planning considers the facility as a dynamic entity. A key requirement for a successful facility layout of the body shop is its adaptability and ability to become suitable for future alterations. The facility we plan today should help Nissan achieve a high supply chain quality (Tompkins, White, Bozer, & Tanchoco, 2010).

Proper facility planning along the supply chain ensures that the material will follow the supply chain series buy-make-move-store-sell to the satisfaction of the ultimate customer. The proposed facility designs in the development of this project's solution should take the following elements into consideration:

- Flexibility. Flexible facilities can handle various requirements without being altered.
- Modularity. Modular facilities have systems that cooperate efficiently over a wide range of operating rates.
- Upgradeability. Upgraded facilities gracefully incorporate development in equipment systems and technology.
- Adaptability. Implications that should be considered include calendars, cycles and peaks on the manufacturing line.
- Selective operability. This is the understanding of how each facility section operates and allows contingency plans to be implemented.
- Environmental and energy friendliness. The Leadership in Energy and Environmental Design (LEED) process should be adopted.

A facility should be continuously improved to satisfy its constantly changing objectives. The process of facility planning can be approached in an organized, systematic way. It can be applied as follows:

1. Define the problem
    a. Define the objective of the facility
    b. Specify the primary and support activities to be performed in accomplishing the objective
2. Analyse the problem
    a. Determine the interrelationships among all activities
3. Determine the space requirements for all activities
4. Evaluate the alternatives
5. Select the preferred designs
6. Implement the design

Facility planning is a key tool used during the Solutions Development phase of this project. AutoCAD is used to draw the current layout of the facility, as well as proposed designs of various ways that the layout can be improved on. Each of the elements listed above are taken into consideration to design the best possible proposal.

Material Flow System with regards to Facility Planning
The principle of minimizing total flow represents the work simplification approach to material flow. This includes:

- Eliminating flow by planning for the delivery of materials, information or people directly to the point of ultimate use and reducing any steps in between.
- Minimizing multiple flows by planning for the flow between two consecutive points of use to take place in only a few movements.
- Combining flows and operations where possible.

All parts in the X90 Body Shop is currently being repacked in some way – whether onto line-side tables, cardboard boxes or special racks. Some of these parts could possibly be supplied directly to the work stations - eliminating repacking steps and minimizing material flow.

Aisle Space Specifications
Aisles should be designed to promote effective flow. Planning aisles that are too narrow may result in congested facilities having high levels of safety and damage problems. On the other hand, planning aisles that are too wide may result in wasted space and poor housekeeping practises. Aisle width should be determined by considering the type and volume of flow to be handled by the aisle (Tompkins, White, Bozer, & Tanchoco, 2010).

Safety issues arise when operators and material handling equipment use the same aisle. Aisles should be straight and column spacing should be taken into consideration during layout of the aisles. Columns are often used to border aisles but rarely should be located in an aisle. For best space utilization, aisles along the outside wall of the facility should be avoided.

Orderliness is a principle that emphasizes that good 'warehouse keeping' begins with the basic principles of housekeeping. Aisles should be well marked with tape or paint. If this is not done, materials will begin to infringe on the aisle space, and accessibility to material will be reduced.

Currently, forklifts and operators move in the same aisle in the X90 Body Shop. In the proposed facility layouts in the Solutions Development, separate aisles will be included for operators and their trolleys to move, as not to coincide with the forklift aisles. There are steel columns that have to be taken into consideration during development of the various facility layouts.

Safety considerations during Facility Planning
Safety should not be an afterthought when designing a material handling solution. By engineering safety into a design, dependence on process controls or personal protective equipment can be side-stepped. Most material handling equipment suppliers provide OSHA-compliant equipment, but this does not necessarily guarantee a safe work place.

The key to a safe facility is concentrating on the interface between the workforce and equipment. A common shortfall in facility planning is poor layout of the rack area. Many planners focus so hard on space efficiency and fail to provide sufficient aisle width for the type of vehicle used. Aisles that are too narrow will result in damaged uprights, damaged vehicles and injured operators.

Nissan outsources the procurement of material handling equipment. All of the equipment (including forklifts) complies with safety standards as determined by Nissan.

Constructing a layout plan

Once all necessary data are collected, a systematic procedure can be used to construct the facility layout alternatives. These steps were followed during the drawing of current and proposed facility layouts of the X90 Body Shop.

1. Select the scale
2. Decide on the method of representation
3. Obtain layout plan supplies and/or hardware and software
4. Locate all permanent facilities on the layout plans
5. Locate the exterior wall that includes the receiving function
6. Locate all columns
7. Locate all manufacturing departments and equipment
8. Locate all personnel and plant services
9. Audit the layout plan
10. Finalize the layout plan

All designs done on AutoCAD for the proposal to Nissan and Schnellecke teams are drawn to scale and with ample detail. Future alterations could easily be added to these drawings, and the remaining body shop area could also be added to the current layout drawing if necessary.

OSHA Act

The Occupational Safety and Health Act was passed to "assure so far as possible every working man and woman in the workplace safe and healthy working conditions and to preserve human resources" (Freivalds, 2009).

Under the act, the Occupational Safety and Health Administration was created to:

- Encourage employers and employees to reduce workplace hazards and to implement new, or improve existing, safety and health programs.
- Establish 'separate but dependent responsibilities and rights' for employers and employees for the achievement of better safety and health conditions.
- Maintain a reporting and record-keeping system to monitor job-related injuries and illnesses.
- Develop mandatory job safety and health standards, and enforce them effectively.
- Provide for the development, analysis, evaluation and approval of state occupational safety and health programs.

Furthermore, the act states that it is the employer's responsibility to become familiar with standards applicable to their establishments and to ensure that employees have and use personal protective gear and equipment for safety.

Nissan already has a strict set of rules and regulations in place concerning safety in the workplace and on the manufacturing floor. Consultation with floor managers during the development of this project will ensure full adherence to all safety regulations necessary.

CHAPTER 3: SOLUTIONS METHODOLOGY

Appropriate Methods, Tools and Techniques

Some tools and techniques are identified during the Literature Review that may help solve points raised in the Problem Statement. Each of these methods is explained thoroughly in the Literature Review, and will not be excessively repeated in this section.

Tools, techniques or methods that will be used during the course of this project include:

- Methods Engineering; used to study all productive and non-productive elements of an operation
    - Develop descriptions and sketches of work stations using AutoCAD.
    - Construct flow process charts. This chart is especially valuable in recording nonproduction hidden costs, such as distances travelled, delays and temporary storage.
    - Principles of Work Design with respect to:
        - Motion economy, manual work, workplace
        - Work environment, safety
- Lean Manufacturing
    - The 5 S's: a visual housekeeping technique that creates a workplace suited for visual control. Two of these that will be applied:
        - Seiso: clean-up, apply good housekeeping principles
        - Seiketsu: maintenance of the system that you have set up
- Facility Planning
    - Draw the current facility layout in AutoCAD
    - Design proposed layouts in AutoCAD
    - Determine aisle widths
    - Select and design material handling equipment such as racking, trolleys and line-side tables
    - Select the best layout for proposed implementation

Supporting Tools and Techniques:

- Time Studies
- Job/worksite Analysis Guide
- Risk Assessment
- Gantt Chart to show the anticipated completion time for each deliverable of the project
- Decision Matrix

Action Plan

This section will explain what is done to address the problems as formulated in the Problem Statement. Thoroughly working through the Literature Review, tools and techniques are identified for reaching the project aim. Each problem to be considered is listed below, along with an explanation of the tools that will be used to address and improve on the current state.

1. Analyse existing work methods: Using Methods Engineering.
    a. Use of job/worksite analysis guide, flow process charts and other exploratory tools such as developing sketches and descriptions for individual work stations.
    b. Collect engineering data e.g. Bill of Material and operator utilization calculated using Time Studies; manufacturing and cost data will be collected where possible.
    c. Study productive and non-productive elements of an operation at each work station.
2. Do time studies on current SLS material handlers/operators.
    a. A template is created for the time study of the Repack Process.
    b. Calculations are done in Excel to determine the operator’s % utilization.
3. Find space near the workstations to use as repack area; clean up space for implementation.
4. Design a proposed line-side table, trolley and racking.
    a. Use facility planning to solve space constraints (creating a leaner assembly line).
    b. Receive operator input from Nissan and SLS operators.
5. Create a more ergonomic workplace: Use motion studies and operation analysis to determine best practise for operations at the work stations and reduce materials handling.
    a. Study manual work design to choose techniques for improvement in this area.
    b. Investigate operators to determine whether they are operating within human capabilities and limitations.
6. Improve safety in the workplace.
    a. It will be ensured that there is compliance to basic OSHA safety regulations. Hazards will be eliminated, and failures can be minimized by increasing reliability, monitoring and standardization.
    b. Determine optimal placement of thermoplastic in welding workstations.
7. Draw current and proposed facility layouts on AutoCAD for the new Repack Area.
    a. Take all client specifications into account.
    b. Ensure optimal space utilization.
    c. Draw a Spaghetti Diagram for the proposed layouts.
    d. Use a decision matrix to choose the optimal layout.
    e. Ensure that part numbers in the area correlates with the part numbers on the BOM.
8. Suggest a proposed repack process.
9. Determine the cost of implementation for the selected layout.
10. Implementation of all suggestions made during the project. Quality standards will have to be enforced by floor managers.
11. Operators have to be trained on the new process implemented.

This action plan is subject to change as each problem is addressed during Solutions Development. With each problem being addressed, alternative solutions could arise. Each solution should be weighed against costs of implementation to determine whether it would be worth the time and efforts of implementation.

CHAPTER 4: DEVELOPMENT OF SOLUTION

Proposed Solution

- Implement a Repack Area close to the production line
  - An adequately sized area is identified as shown later in this document
  - The area has sufficient space for future allocation of more boxes
  - The area is cleared out and demarcated over approximately 3 weekends
- Design racking for this area
  - Boxes can be replenished on floor level as well as one level up.
  - Only two levels are plausible, as a repack operator will not be able to reach to another level.
  - Racking is a standard size.
- Design a standard line-side table that will accommodate the largest part as well as bins for medium parts.
- Design bins large enough to accommodate all medium parts.
- Design a standard trolley to accommodate the largest parts as well as the bins for medium parts.
- Let the boxes be delivered to a marshalling area in the Repack Area.
- A smaller forklift moves boxes from the marshalling area to the designated racking with coinciding part number as indicated on the floor/on rack.
- Let small boxes be supplied directly to line-side by supplier, thus no handling by repack operator at all. These small parts will be supplied into pigeon-hole racking. These line-side racks have small openings resembling pigeon holes.
- Three proposed layouts are designed to give the client a choice regarding the layout of the new repack area.

The Repack Area

An area is identified to be used as a Repack Area. This will create a closed and safe environment for boxes to be placed, repacked to a trolley and moved to line-side tables. The design of trolleys and line-side tables will be as standard as possible, for lowest cost and ease of implementation.

This area is based mainly on the Facility Planning principle of visual management. It has the features of identification, housekeeping and organization (one place for everything, and everything in a place). The operators can relate to a place that they can identify as their own; a clean environment with clear control over the state of the work. A concentrated space also increases the effectiveness of supervision.

The boxes currently found in this area will be removed by responsible parties and cleaned out.

When designing proposed layouts for the Repack Area, a Marshalling Area should be included, forklift and trolleys must have enough aisle width for proper movement, and these aisles should never cross or meet (to avoid safety issues).

The forklift must have ample space to replenish boxes, requiring approximately a 3.5m wide aisle. The trolley aisles need only be approximately 2m in width - enough space for an operator to repack parts from boxes to the trolley. The aisles should preferably be straight, and the design should take all steel columns into consideration to avoid safety issues.

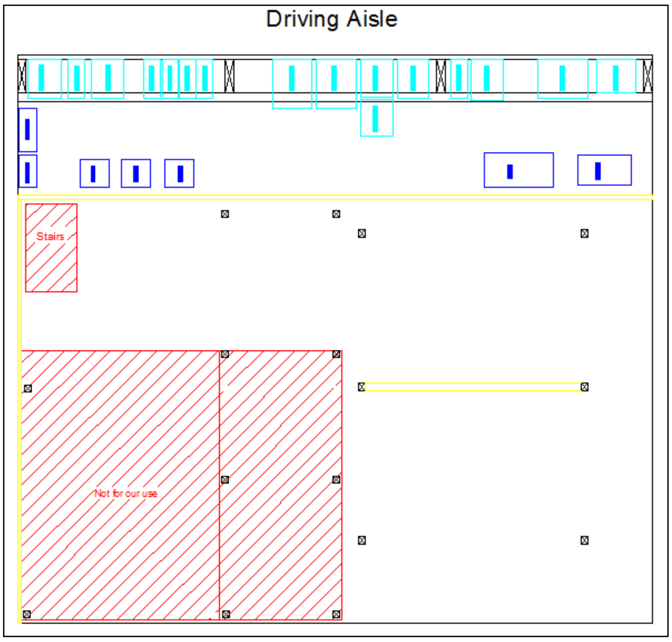
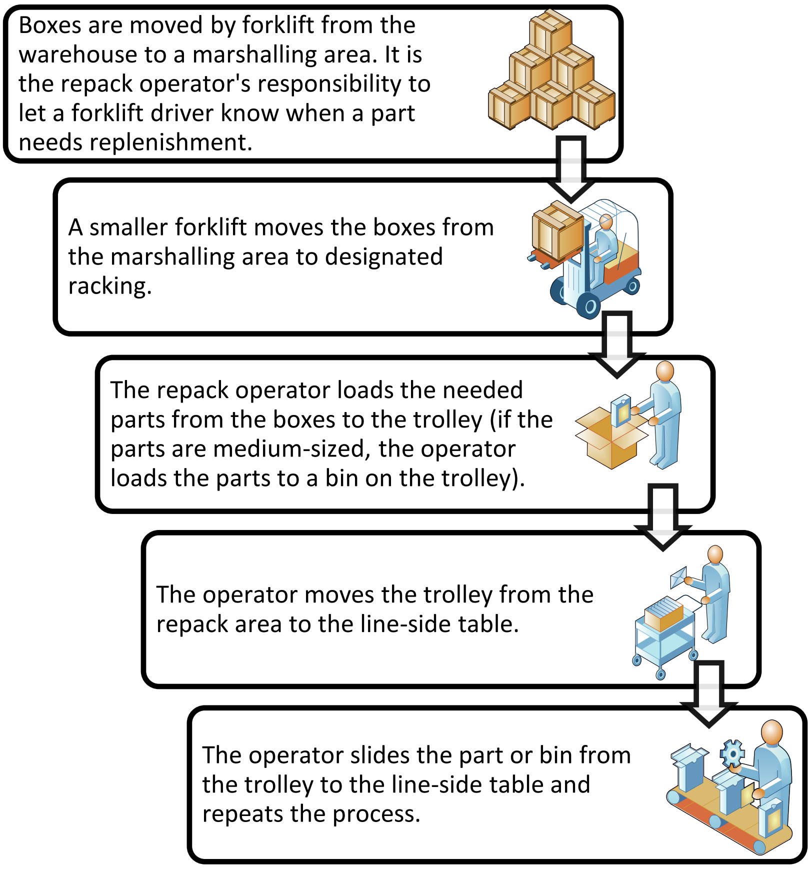


Figure 17: Space available for proposed Repack Area as drawn on AutoCAD

The proposed process to follow for repacking:



The Racking

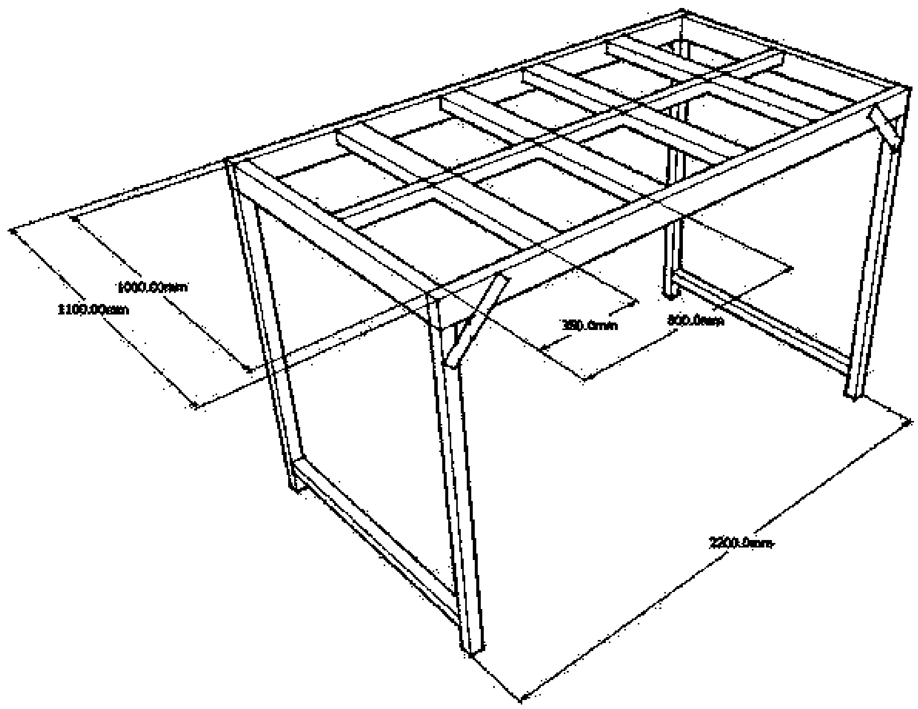


Figure 18: Racking as designed by Schnellecke team

Racks are designed for the repack area to make best use of space for storage of boxes. This will enable a forklift to replenish boxes on two levels rather that the current method of replenishing boxes to floor level. The type of racking chosen for this project is called a Single-Deep Selective Rack. It is a simple construction of metal uprights, and provides immediate access for the forklift as well as the operator to each box stacked.

The racks are designed at a comfortable height for the repack operator to pick parts from the selected box with optimal ergonomic movement (as is discussed in the Literature Review).

The boxes do not need to be stackable (as they are placed on a rack and not on top of another box), and may be of varying heights and widths. Since the storage requirements are only one box per part number, a single-deep rack is adequate for this Repack Area.

These racks will be fastened to the floor with bolts that are easy to remove, in order to make it easier if the layout of the repack area should change in the near future.

The trolleys

The trolleys should have the ability to accommodate the largest parts. The medium sized parts will be repacked into a bin and then placed onto the trolley. The small parts will be supplied directly to the line and not repacked at all. This will ensure that the parts are only handled by the supplier and reduce time of material handling. It will give the repack operator more time to concentrate on the repacking of larger parts.

The trolley is a standard design of 0.6m in width, 1.4m in length and 0.912m high. This standardization of material handling equipment enables interchangeability and simplifies operator training. The trolley surface is covered with roller wheels. These wheels enable the repack operator to simply slide the parts or bins from the trolley to the line-side table. It gives the operator the chance to do the job faster with less fatigue and greater safety.

The handle enables the operator to easily steer the trolley, and raised sides ensures that bins and parts cannot slide off the side of the trolley while in motion. This also acts as guides when the bins are slid on and off the trolley.

Standardization of the trolley leads to lower design, implementation and maintenance costs.

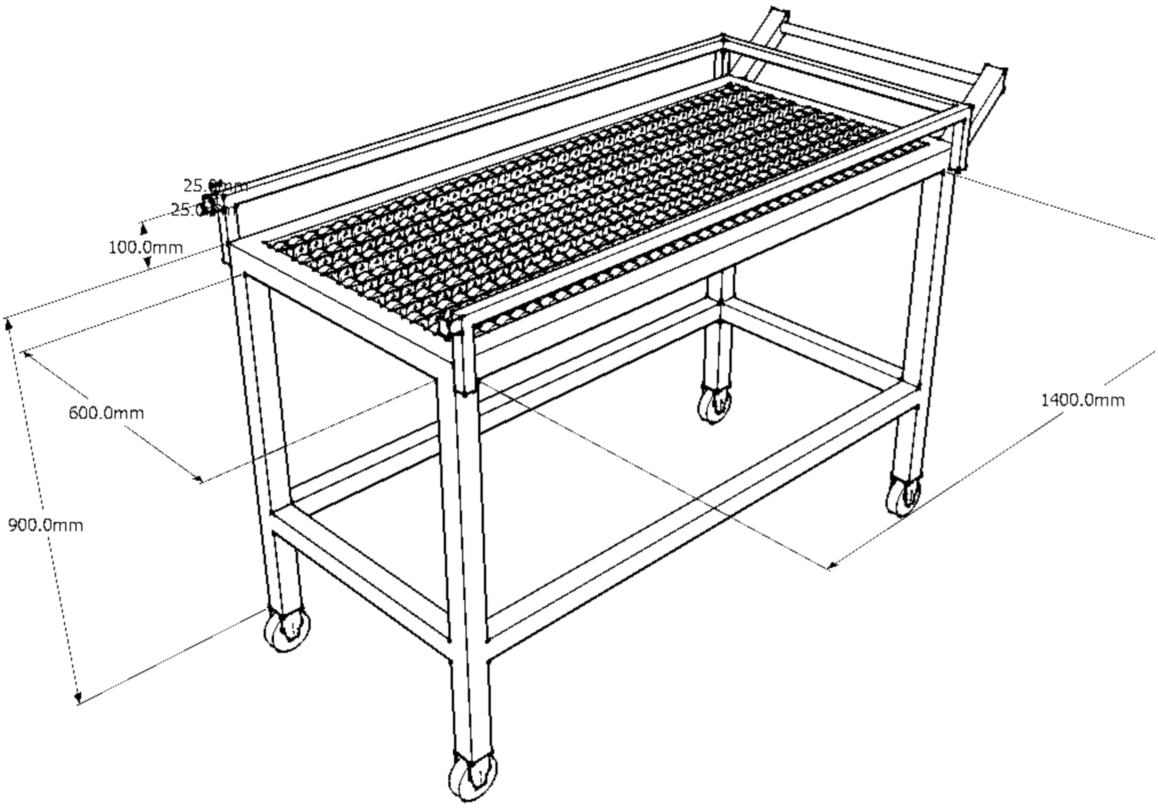


Figure 19: Trolley as designed by Schnellecke team

The line-side tables

The line-side tables are a standard design of 0.9 x 1.55m – slightly lower than the trolley, to ensure easy exchange of parts from the trolley onto the line-side table.

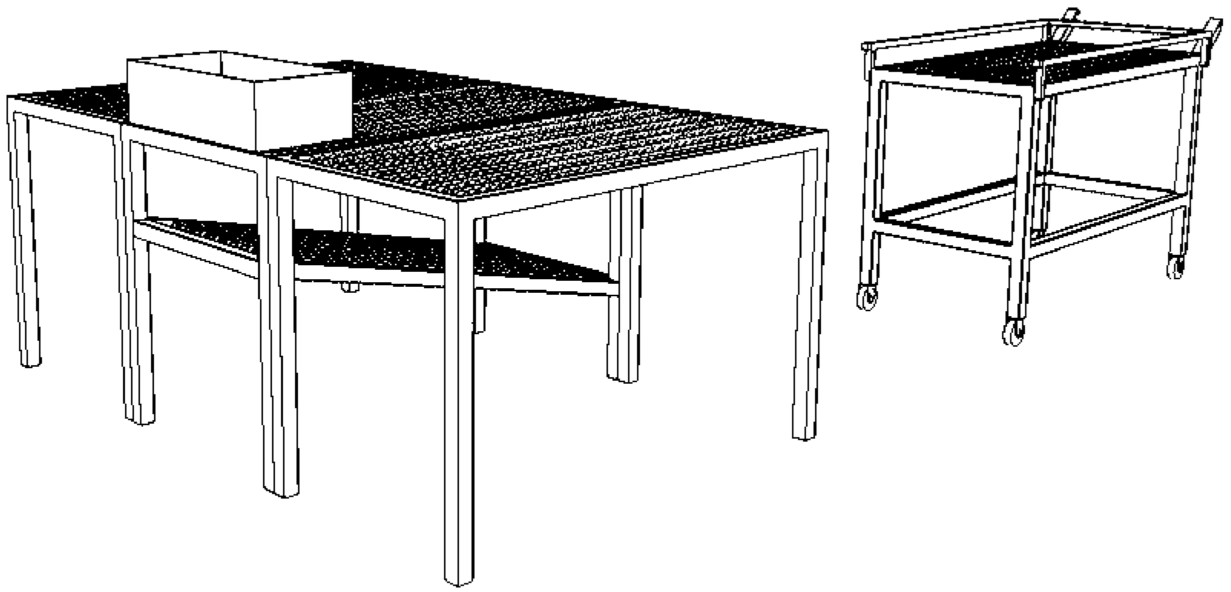


Figure 20: Line-side tables as designed by Schnellecke team

The surface of the line-side tables also have roller wheels for the parts and bins to simply be slid from trolley to table. The table is able to accommodate the largest parts as well as bins for the medium parts. It is not necessary for the table to be mobile. An additional tilted surface (similar to a gravity chute) is designed below the table surface, where bins are placed once empty. This also acts as a visual indication to the operator that a certain part is in need of replenishment.

The standardization of the line-side tables saves costs during purchase as well as repair, as standard parts are used for all tables. This is also true for the racking and trolleys designed.

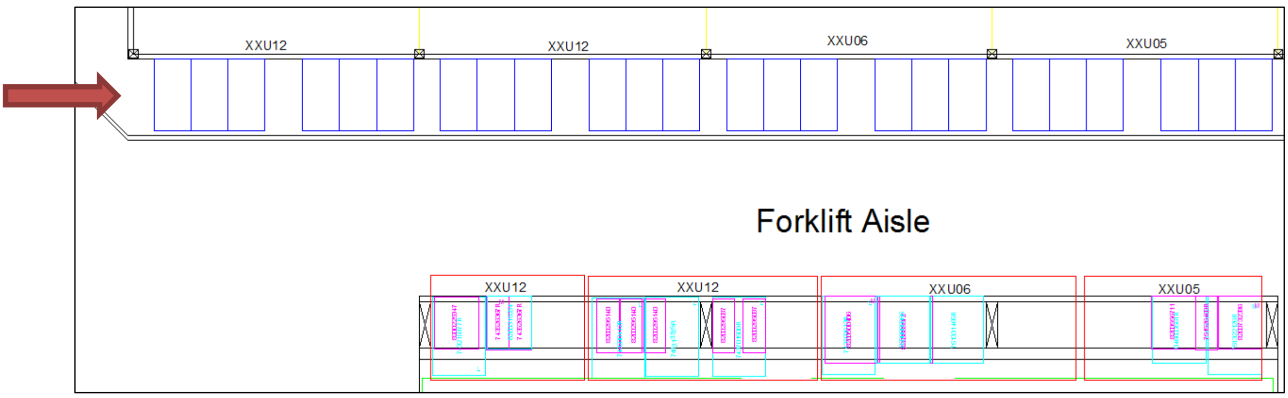


Figure 21: Layout of the line-side tables

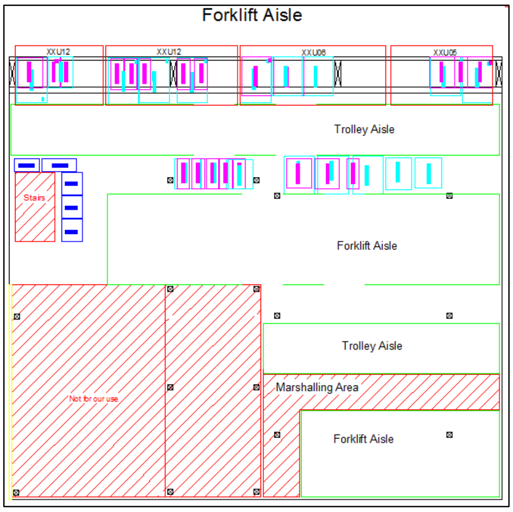
The figure shows the position of the line-side tables (dark blue), approximately 6 tables per work station, with a total of 24 tables.

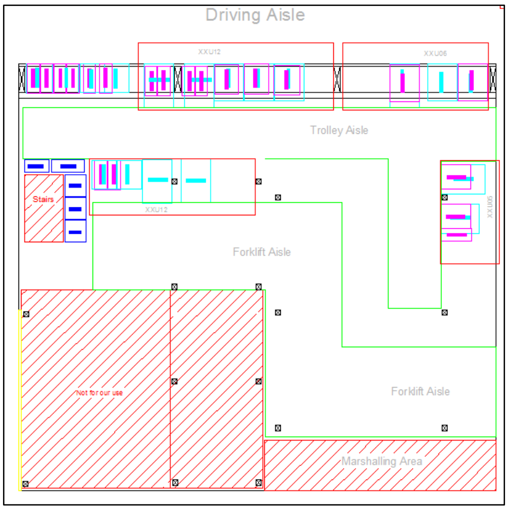
Proposed AutoCAD layouts

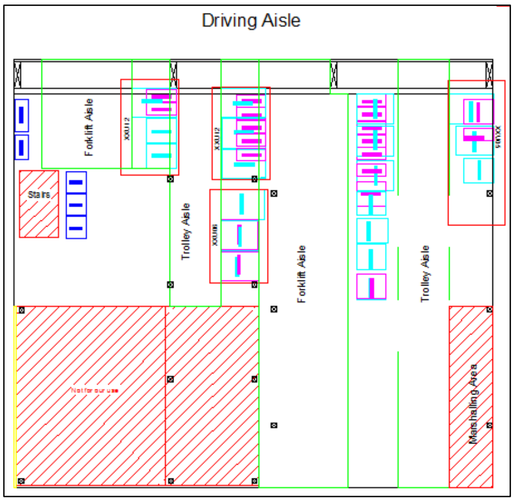
Three layouts of the Repack Area are designed on AutoCAD to be proposed to Nissan and Schnellecke management. Each proposal indicates the areas assigned to parts from workstation XXU12, XXU06 and XXU05 with red. All boxes are placed in a manner that will ensure easiest access for operator to move parts from Repack Area to line-side.

According to Facility Planning principles, the proposed areas are all flexible; the areas for placement of boxes are only demarcated on the floors and no physical walls are built. This enables for future changes to be implemented with ease as only the floor demarcation need be changed and the racking moved around. The area is upgradeable if it is found necessary in the future – a new repack system could be implemented without any problems. The only restriction in this area is the steel columns which cannot be moved without overspending the budget.

As is clear on the proposed designs, trolley and forklift aisles never coincide. This is done to ensure safety in the Repack Area and avoid unnecessary accidents. Thermoplastic (indicated in yellow on drawing) is removed where possible to increase the operator's mobility in and around the area. A wall is taken down, all the boxes currently in the area are cleared out and the area is properly cleaned up. Painted demarcation lines on the floor are removed and repainted as on the chosen proposed layout. The Cyan coloured boxes are on the floor level, and Magenta coloured boxes are on the first level of the racking. The overall layout of each design can be compared below.







Proposed Layout A

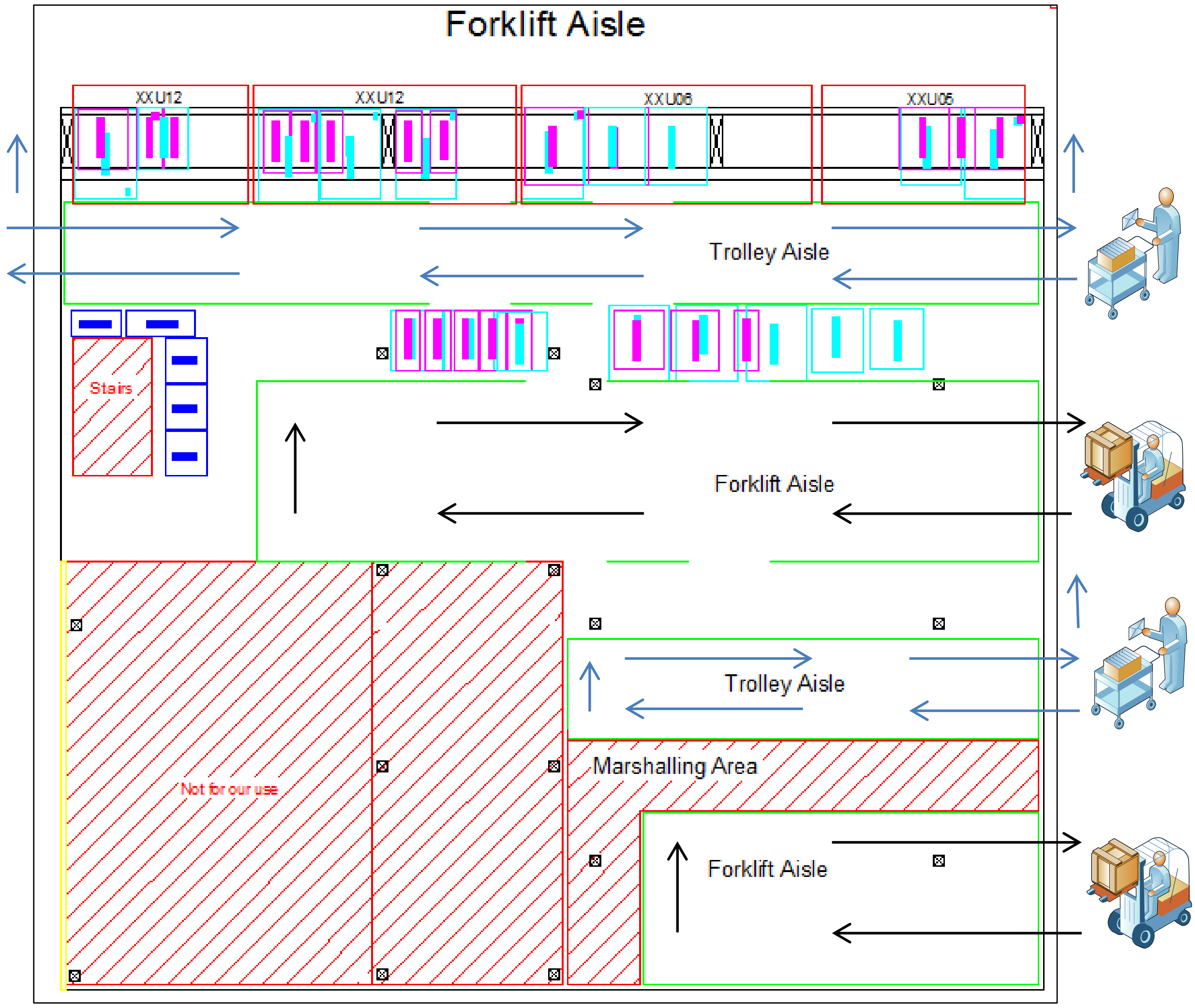


Figure 22: Proposed Layout A

The marshalling area is out of the repack operator's way. The design is easy to understand and install. The aisles used for operators and forklifts are separated and never cross; this is critical for safety reasons.

The aisles are straight while curves, jogs and non-right angles are avoided – lowering the chance of a shop floor accident. This is not the design with the highest m² of the three proposals, but it will have a low cost of implementation.

A spaghetti diagram is also done for each proposed layout, indicating the flow of movement for both forklift and operator.

Proposed Layout B

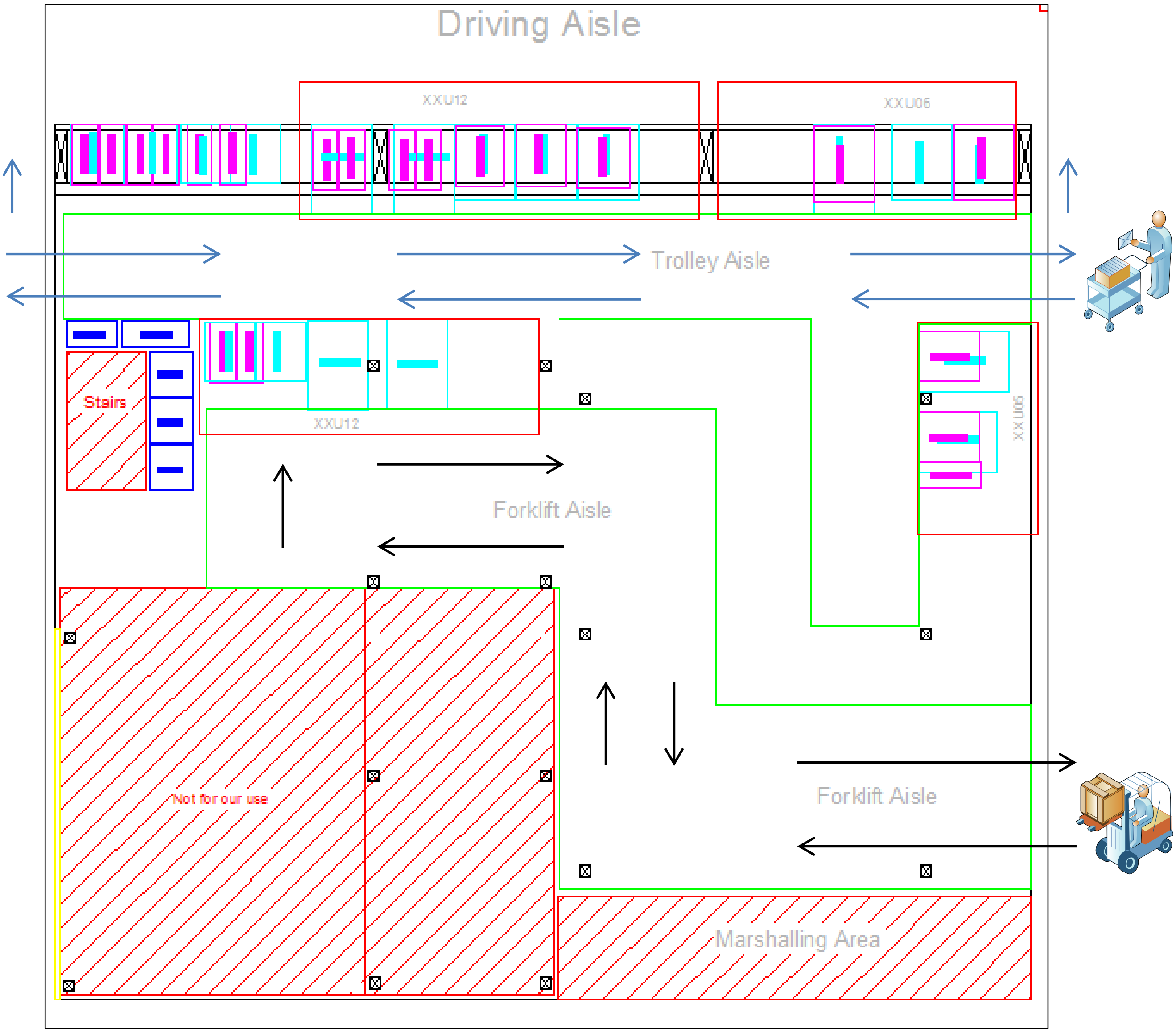


Figure 23: Proposed Layout B

The design might be more difficult to understand and install, but the repack operator only needs to enter one aisle to be able to repack all necessary parts; the flow of his movements is not interrupted. This design also has a better space utilization as there are more m² available than with Proposed Layout 1. The marshalling area is out of the way, but might not be big enough for future expansion.

The columns in the forklift aisle are a safety hazard - demarcation lines should be painted and plastic covers will have to be placed around them, increasing implementation costs.

Proposed Layout C

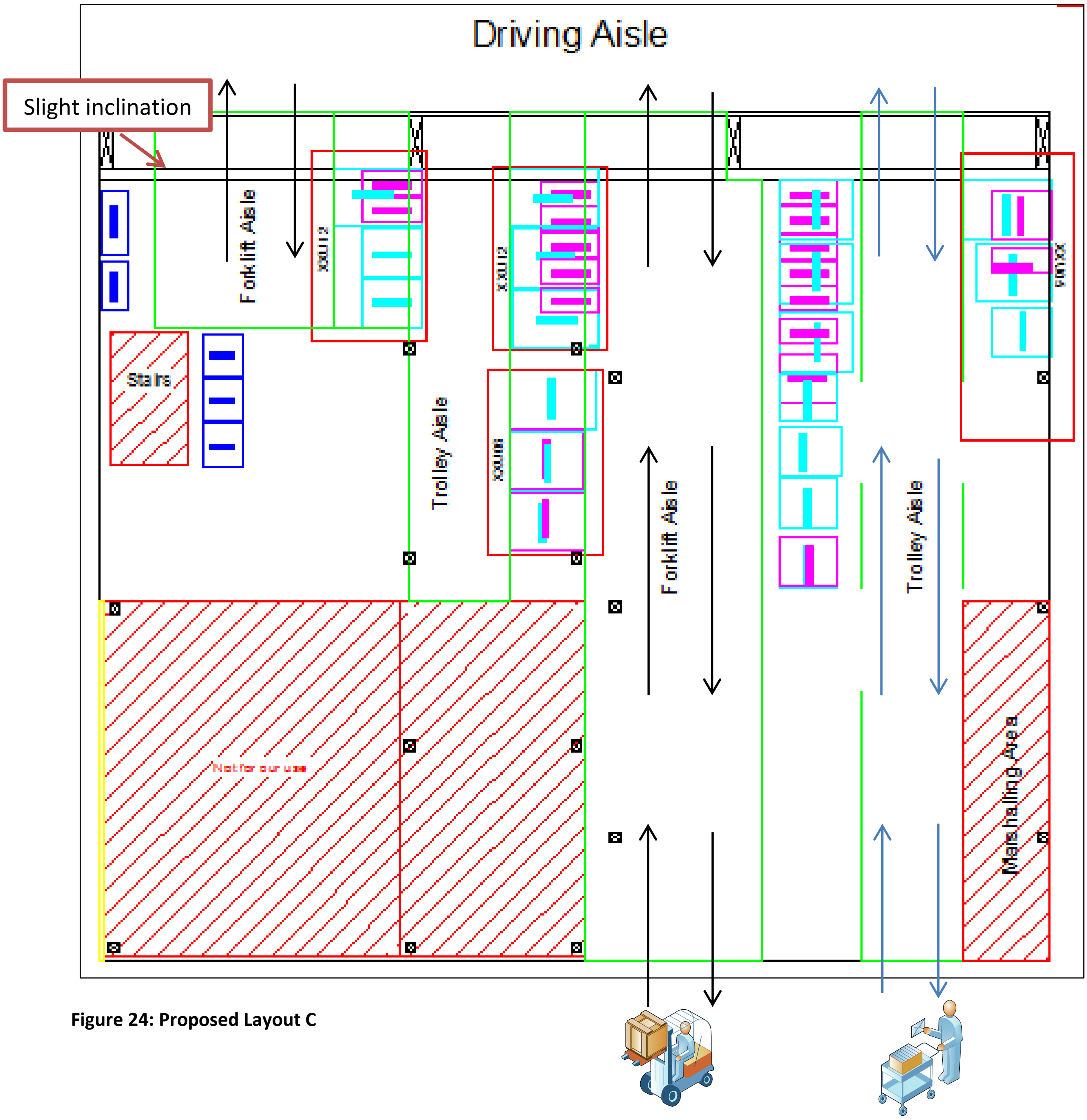


Figure 24: Proposed Layout C

This design will be the most expensive to implement, as the steel columns on the right hand side are moved to accommodate the Trolley Aisle. These columns cannot be removed entirely, but it will be possible to move them slightly for this design.

This design is simple and easy to understand with straight aisles. The parts can be fed directly to the line with ease. The line that separates the Repack area with the Driving Aisle has a slight inclination (as indicated in the sketch). This might pose a problem to the handling of the trolley and should be demarcated clearly.

Decision Matrix

The client might have an immediate liking toward one of the proposed designs, but to ensure that a technically sound decision is made, we will make use of a decision matrix.

Certain criteria are listed, and a weight of importance is assigned to each (as determined in conjunction with the client). A rating is then given to each criterion, and a final count is calculated to which proposal will be best for implementation.

A decision matrix allows decision makers to structure their problem by:

- specifying and prioritizing their needs with a list a criteria; then
- evaluating, rating, and comparing the different solutions; and
- selecting the best matching solution

Criteria (listed in order of importance):

1. m² space available for racking; this is the most important criteria as the main cause for congestion in the current body shop area is a lack of space.
2. Cost of implementation
3. Simplicity of implementation
4. Ease of access to manufacturing line; can the operator move the trolley directly to the required work station, or does he have to move around other boxes or racks.
5. Ease of movement for trolley and forklift; are the operator and forklift aisles separated, straight and safe.

		Alternatives					
		Layout A		Layout B		Layout C	
	Weight	Rating	Score	Rating	Score	Rating	Score
Criterion 1	*5*	3	15	4	20	4	20
Criterion 2	*4*	4	16	3	12	1	4
Criterion 3	*3*	4	12	2	6	2	6
Criterion 4	*2*	3	6	4	8	5	10
Criterion 5	*1*	4	4	2	2	4	4
Total	**15**		**53**		**48**		**44**

Score = Rating*Weight

According to the decision matrix, proposed layout A would be the best choice for implementation. It will have the lowest cost of installation, is the most simple to implement and train the operator in, and the trolley and forklift can move safely around the aisles with ease.

Even though this layout does not have the most m² available for placement of boxes, there is still enough space open for future additions of part numbers and changes to be made. The Marshalling area is far from the line (as requested by the client) and would not disrupt the process of repacking. Since installation will be so simple, it will also be easy to change the design or layout in the future if necessary.

Budget

A predetermined amount of approximately R35000 is made available by Schnellecke for the implementation of this project. This is an estimate, and if the project should cost more than this amount, a meeting should be held with the Schnellecke and Nissan team to determine where cost cuts could be made, or if permission could be granted for a higher amount to be made available for installation.

To implement this project, three weekends will have to be utilized (when the manufacturing line is not active) so as to not disturb the production in the Body Shop area. Two forklift drivers will be appointed to work on Saturdays (three full days of 8 hours) with due overtime payment of 1.5 times normal hourly wages as indicated by contract. There will also be appointed two operators to help with moving of boxes, breaking down of temporary walls and removing thermoplastic sheets. The hourly wages for a forklift driver as well as operator at Nissan, Rosslyn, is R35/hour.

The trolleys, line-side tables, racking for the proposed repack area as well as the bins are produced on-site and not outsourced. This saves time and money in the implementation of this project. It also reduces cost of repairs, as parts are standardized and a trolley could simply be sent to the Repair Centre when a problem is encountered.

Cost of implementation

The cost of line-side tables, trolleys, racking and bins have been provided by the material equipment manufacturing centre at Nissan, Rosslyn.

Item	Amount and Cost	Calculation	Actual Cost
Line-side tables	24 @ R450	24 x 450	R10 800.00
Standard trolleys	2 @ R800	2 x 800	R1 600.00
2 wide 1 deep Racking	12 @ R1000	12 x 1000	R12 000.00
Bins for medium parts	30 @ R150	30 x 150	R4 500.00
Unforeseen costs			R3 000.00
Total Cost of Implementation			**R31 900.00**
Budgeted Amount			R35 000.00
Amount under budget			R3 100.00

Note that no wages are included for forklift drivers and other operators over this period of time, as it is added to their monthly salaries and does not have to be taken into account in this budget.

Even though the final amount spent on the project implementation is under budget, the client has the final say on whether they would like to implement the project or not.

CHAPTER 5: CONCLUSION

The project has already been presented to the Nissan and Schnellecke team. The feedback was very positive, and the project is currently in a testing phase where prototypes of the racks, line-side tables, trolleys and bins are manufactured for a trial run. Schnellecke managers suggested that this project and the designs in the Solutions Development chapter be used as blueprint for future clean-up and optimization of the entire Body Shop (not just the X90 area).

Conclusions on various topics are discussed below.

Reduction of waste as defined by Lean principles

The implementation of a new Repack Area and repack process will reduce waste as defined in the Literature Study of this document.

Ways in which this is true are listed below:

- Fewer inventories are kept per part number, as only one box per part is kept in the Repack Area. It is the operator's responsibility to request a forklift driver to replenish a box when it is empty.
- Waiting time at the manufacturing line is lower, since there is an orderly system of where parts are stored – the operator does not have to walk around the entire Body Shop looking for boxes.
- Motion in terms of material handling is minimized with the design of roller wheels on all material handling equipment's surfaces.
- Fewer defective items are present as poor repack methods are no longer used. Parts are not repacked from box to box, but from box to trolley and then to a line-side table. This also ensures that a FIFO sequence is followed.
- Since all repack processes are standardized, there is an increased process understanding.
- All small parts are now supplied directly to the manufacturing line by the suppliers; this non-value-adding element is eliminated from the operator's repack process.

Standardization of Repack Process

Great care was taken in standardizing all material handling equipment – the racking, trolleys, line-side tables and bins. Equipment standardization is important since it simplifies operator training, allows equipment interchangeability and ensures a simpler repair process during breakdown.

The layout and material handling equipment is interchangeable as part numbers can easily be added or removed. This is especially necessary when a new automobile model is added to the production line.

According to lean manufacturing principles discussed in the Literature Review, standardization of processes eliminates non-value adding elements. The proposed process for the repack operations is simple and easy to train an operator in.

Implementation of a closed area for repack operations

By implementing an isolated area next to the manufacturing line, specifically dedicated towards the repack operations, a safe environment has been created. Cardboard boxes are no longer placed directly next to welding stations, eliminating the fire hazard. Boxes no longer stand in the forklift's driving aisle, making the area safer for forklift operators, repack operators as well as any other person walking through the X90 Body Shop.

The forklift drivers and repack operators do not move in the same aisle anymore, creating a safer workplace for both. Placing the marshalling area away from the repack operations is another safety principle integrated in the proposed layout and operations.

Facility planning characteristics (as discussed in the Literature Review) that are present in the proposed layouts include:

- Flexibility. The proposed facility layout can be used for the repack of various stations' parts without being drastically altered.
- Upgradeability. Advances in equipment systems and technology can be incorporated over time with relative ease.
- Adaptability. With changes in cycles and peaks with regards to manufacturing, the layout is adaptable. This is especially important as new models of automobiles could be added to the manufacturing schedule at any time during the course of the year.

Some of the objectives of successful facility planning that have been achieved:

- The support of the organization's vision through improved material handling, material control and good housekeeping.
- Effective utilization of operators, material handling equipment and space.
- Ease of maintenance as a result of standardization throughout the facility.
- Provision of employee safety, job satisfaction and environmental responsibility. Effective supervision is possible in a concentrated environment.

The repack area could be considered as the repack operator's 'workstation'. The following general guidelines were followed in creating this repack work space:

- The area is designed for the operator to pick and move material without long or awkward stretches.
- It is designed for effective and efficient utilization of the operator. Since the operator has to move a distance from the repack area to the manufacturing line with the loaded trolley, the operators' time is now fully utilized.
- Time spent handling material during repack is minimized.
- Factors such as an operator's safety, comfort and productivity are maximized.
- Hazards, fatigue and eye strain is lowered.

Ergonomics of operator using proposed process

The racking, trolley and line-side table designs all took into consideration the ergonomic movements of the operator. In the Repack Area, boxes are replenished on floor level as well as a first level. Both these levels are easy for the operator to reach and pick parts from boxes without having to strain or lift parts higher than his torso.

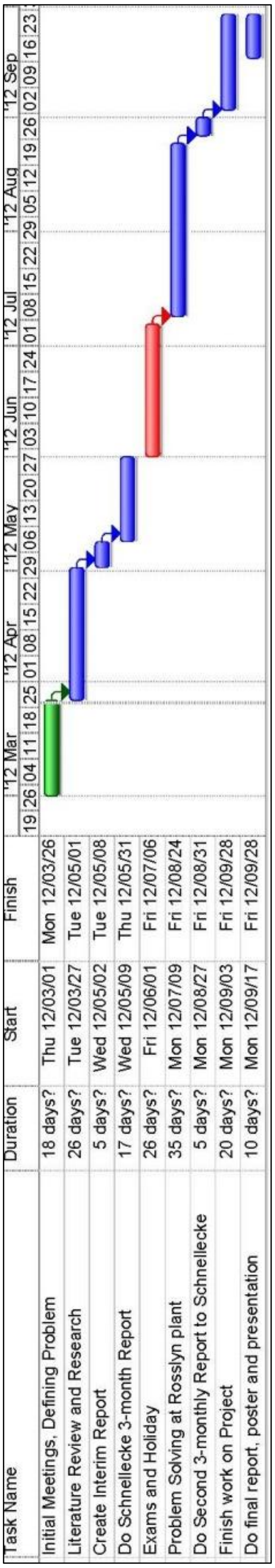
The operator is responsible for tasks such as picking parts from boxes, loading the parts to bins or a trolley, pushing the trolley and sliding parts from the trolley to a line-side table. Each of these tasks can be done by coordinating movements around the centre of the body, as each trolley and table is designed at an optimal height to ensure this (as seen in the figure below). The operator's movements are now continuous, curved, natural and makes use of momentum. Rhythmical and habitual flow patterns are possible, which reduces mental, eye and muscle fatigue and strain.

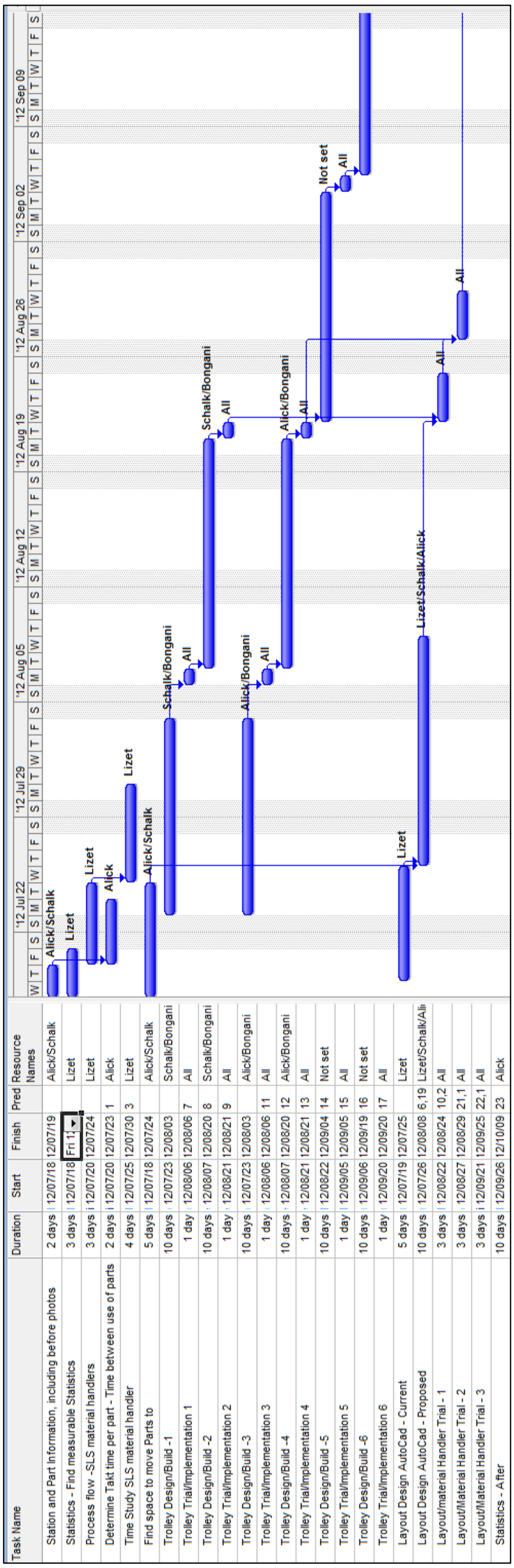
Principles of Work Design that were used:

- Maximum muscle strength is achieved at midrange of motion. The trolley and line-side table are at the same comfortable height to enable this. The trolley handle is at a comfortable height for the operator to use minimum strength while pushing it around.
- Maximum muscle strength is achieved with slow movements; the tasks consist of no rapid movement and the operator will be trained in safe repacking practises.
- Momentum is used to assist the operator during the repack process, as the trolley, racking and tables are designed with roller wheels to ensure that parts and bins can be slid easily from one to the other.
- The operator's large muscle groups are used for tasks requiring strength (picking heavy parts from a box).
- The tasks are design so that most workers can do them; an operator of almost any age, size, weight and fitness level will be able to complete the tasks as explained in the proposed process.
- Tasks are designed so that one operator does a variety of tasks such as reaching, picking, loading, walking and pushing. The operator uses different muscle groups for each task and does not strain one muscle group from repetitive work. A variety of tasks also ensures that the operator does not become bored with the job at hand.

APPENDICES

Appendix A: Gantt Charts





Appendix B: Time Studies

Time Study Observation Sheet | Form: Q001 | SCHNELLECKE LOGISTIC SERVICES

Study No			
Date	2012/07/18		
Sheet	1	of	1
Observer	L. Engelbrecht	Department	X90 Body Shop
Operator	Matthews	Operation	Repacking
Supervisor		Machine Involved	
Unit	240		
Build / Shift	240		
Time / Shift	460		

El No	Element Description		Observed Time 1	2	3	4	5	6	Avg. N Time	Freq / Shift	Number Operators	STD Time
1	Open box and remove plastic packaging.	R	1.00	1.00	1.00	1.00	1.00	1.00	0.511	17	2	17.378
		OT	0.250	0.500	0.467	0.600	1.000	0.250				
		N	0.250	0.500	0.467	0.600	1.000	0.250				
2	Pick part from box.	R	1.00	1.00	1.00	1.00	1.00	1.00	0.150	278	2	83.400
		OT	0.083	0.150	0.117	0.133	0.250	0.167				
		N	0.083	0.150	0.117	0.133	0.250	0.167				
3	Load part to table/rack/line-side box.	R	1.00	1.00	1.00	1.00	1.00	1.00	0.158	343	2	108.045
		OT	0.112	0.100	0.067	0.158	0.175	0.333				
		N	0.112	0.100	0.067	0.158	0.175	0.333				
4	Fetch flat trolley for small parts from market area and move to station.	R	1.00	1.00	1.00	1.00	1.00	1.00	0.625	10	2	12.500
		OT	0.333	0.500	0.833	0.833						
		N	0.333	0.500	0.833	0.833	0.000	0.000				
5	Load box to flat or bin-type trolley.	R	1.00	1.00	1.00	1.00	1.00	1.00	0.151	80	2	24.213
		OT	0.122	0.189	0.122	0.172						
		N	0.122	0.189	0.122	0.172	0.000	0.000				
6	Unload parts from flat or bin-type trolley to the centre of the station.	R	1.00	1.00	1.00	1.00	1.00	1.00	0.633	80	2	101.333
		OT	0.400	1.000	0.533	0.600						
		N	0.400	1.000	0.533	0.600	0.000	0.000				
7	Move empty trolley back to market area.	R	1.00	1.00	1.00	1.00	1.00	1.00	0.556	10	2	11.111
		OT	0.333	0.500	0.833							
		N	0.333	0.500	0.833	0.000	0.000	0.000				
8	Hand out packs of screws to operators.	R	1.00	1.00	1.00	1.00	1.00	1.00	1.000	8	2	16.000
		OT	1.000									
		N	1.000	0.000	0.000	0.000	0.000	0.000				
9	Fetch forklift to replenish line-side box.	R	1.00	1.00	1.00	1.00	1.00	1.00	3.000	5	2	30.000
		OT	3.000									
		N	3.000	0.000	0.000	0.000	0.000	0.000				
10	Remove empty box from line-side area.	R	1.00	1.00	1.00	1.00	1.00	1.00	0.404	17	2	13.742
		OT	0.250	0.367	0.417	0.583						
		N	0.250	0.367	0.417	0.583	0.000	0.000				
11	Fetch tools from team leader, open line-side case and put tools away.	R	1.00	1.00	1.00	1.00	1.00	1.00	9.000	2	2	36.000
		OT	9.000									
		N	9.000	0.000	0.000	0.000	0.000	0.000				
12	Fetch random parts as requested by operators.	R	1.00	1.00	1.00	1.00	1.00	1.00	3.000	2	2	12.000
		OT	3.000									
		N	3.000	0.000	0.000	0.000	0.000	0.000				
13	Take faulty parts produced to team leader.	R	1.00	1.00	1.00	1.00	1.00	1.00	4.000	3	2	24.000
		OT	4.000									
		N	4.000	0.000	0.000	0.000	0.000	0.000				
14	Visually check content of line-side boxes and report to team leader which parts need replenishment.	R	1.00	1.00	1.00	1.00	1.00	1.00	4.000	4	2	32.000
		OT	4.000									
		N	4.000	0.000	0.000	0.000	0.000	0.000				

	NOTES	APPROVALS	Date		
				Basic Time	521.722
1		IE		Plus:15% Allowances	78.258
2		Supervisor		STD Time	599.981
3		Manager		% Loading	130.43%

Time Study Analysis Sheet

Form: Q001

SCHNELLECKE LOGISTIC SERVICES

Study No	1
Date	2012/07/19
Sheet 1	Of 1

Observer	L.Engelbrecht	Department	Planning	Build	
Operator	Material Handler	Area	Bodyshop - Repacking	Prop build	
Operation	Line Stock Management	Production Build		Shift Mins	460.00

El No		Element Description	Time per Unit	Freq. per Shift	Total Time E	Total Time NE
1		Open box and remove plastic packaging.	0.511	34	17.378	
2		Pick part from box.	0.150	556	83.400	
3		Load part to table/rack/line-side box.	0.158	686	108.045	
4		Fetch flat trolley for small parts from market area and move to station.	0.625	20	12.500	
5		Load box to flat or bin-type trolley.	0.151	160	24.213	
6		Unload parts from flat or bin-type trolley to the centre of the station.	0.633	160	101.333	
7		Move empty trolley back to market area.	0.556	20	11.111	
8		Hand out packs of screws to operators.	1.000	16	16.000	
9		Fetch forklift to replenish line-side box.	3.000	10	30.000	
10		Remove empty box from line-side area.	0.404	34	13.742	
11		Fetch tools from team leader, open line-side case and put tools away.	9.000	4	36.000	
12		Fetch random parts as requested by operators.	3.000	4	12.000	
13		Take faulty parts produced to team leader.	4.000	6	24.000	
14		Visually check content of line-side boxes and report to team leader which parts need replenishment.	4.000	8	32.000	

Key	Description		E	NE
		Basic Time	521.722	0.000
E	Essential Task	Total Basic Time	521.722	
NE	Non-Essential Task	Plus :15% Allowances (P,F&D)	0.150	
	Environmental Task	STD Time	599.981	0.000
▲	Visual Check	Total STD Time	599.981	
▲▲	Quality Check	Percentage Loading	130.43%	

	NOTES	APPROVALS	Date	Signature
1		IE		
2		S/visor		
3		Manager		

Appendix C: Personal Budget

• Internet usage: (based on Vodacom Mofaya rates) 4GB	R400.00
• Cell phone bill (approximation only)	R100.00
• Print of Draft Reports	R200
• Binding of Final Report	R400.00
• Travel: Visiting Rosslyn plant once a week, for approximately 15 weeks at 60km per return trip (cost taken at AA rates)	R1350.00
TOTAL expenditure:	**R2450.00**

Appendix D: Acknowledgements

I would like to offer my gratitude to the Schnellecke team for their assistance during the project. A lot of time and effort was put into helping me around the plant, designing the tables, racks and trolleys.

I would also like to show my appreciation toward the Nissan SA team for hosting me and allowing me to do the project on their premises, using their data and talking to multiple operators, supervisors and managers.

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