## COVER PAGE FOR FINAL PROJECT DOCUMENT (BPJ 420) - 2012

### Information with regards to the mini-dissertation

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<th>Project Title: (e.g. A Contingency framework for the after-sales inventory at Nissans Part Distribution Centre)</th>
<th>Facility Plan for Unilever</th>
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<td><strong>Keywords</strong> (Provide keywords from your project (for searching purposes). The first word of two words must always have a capital first letter and the rest of the words following must be lower case. In the event of an abbreviation, use as it is known. E.g. Economic recession, ABSA, ERP, Simulation modelling)</td>
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<td><strong>Abstract</strong> (Provide an abstract of the mini-dissertation. An abstract is a short summary of the contents covered in the item.)</td>
<td>Using systems dynamics and facilities planning principles to overcome inventory planning and Flow design for a fast moving goods factory.</td>
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### Handtekening

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A Facility and Work Flow design for Unilever

by

Wiseman P. Mbatha
26481121

Submitted in partial fulfilment of the requirements for the degree of

BACHELORS OF INDUSTRIAL ENGINEERING

in the

FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

UNIVERSITY OF PRETORIA

October 2012
Executive Summary

The main aim of this document is to serve as a design recommendation and a recorded documentation for the tactical decisions that had to be made when designing the factory. The report also serves as a design guide line for future projects that will be done by Unilever. The document was created by a student from the University of Pretoria as part of his final year project.

An appendix with the designs and simulation models will be attached at the end of the document. When developing the designs the student had to do research on best practices available in the industry this was done by consulting companies, going on reliable internet sources recommended by the departments’ library and reading articles relating to the subject.

The major challenge that was faced throughout the project is that decisions are made as the project progresses but using industrial and systems engineering a reliable team of people the project progressed without major design problems. The key to the success of the project is that the company keeps record of most of their work which makes it easier to retrieve information when needed.
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1 Introduction

Unilever South Africa (Pty Ltd), a subsidiary of Unilever PLC, is one of the largest Fast Moving Consumer Goods companies in the South Africa. The Company is over 100 years old, with brands that range from tea, homecare to skin care products. Unilever PLC has many employees all over the world, in South Africa Unilever has employees based across two offices and five manufacturing locations in South Africa.

Unilever’s strength is its brands and its people; with Sunlight as Unilever’s biggest selling brand, although others such as Omo, Lux, Lipton, Ola and Knorr are also household names. Unilever operates in nine product categories – laundry, savoury and dressings, skincare and cleansing, margarine, deodorants, household care, tea, hair care and ice cream – and is the market leader in seven of these categories.

The company’s product development and market expertise are global, while strong local roots enable it to fine-tune these to South African needs. Annually, Unilever invests approximately €891m spent on R&D worldwide. Consumer research also plays a vital role in brand development.
2 Project Description

The aim of the project is to design a factory for Unilever. The new factory will be based on an existing factory which is located in Boskburg. The Boskburg factory is currently running three factories which are separated based on the products that are produced in that factory. These are Foods, Powders and the Liquids manufacturing factories. Each of the three factories has different products that are manufactured in different production lines. The powders factory produces powdered soap with brands like Omo, Surf and Skip. The Foods factory produces the well known margarine bands such as Rama, Stork and Rondo Margarine.

The factory that will be redesigned is the Liquids factory and will be the subject of discussion in this report because management has decided to move the liquids factory to a different location and use the current factory as warehouse storage space for packaging material storage. The new factory will be located within a 5 km radius from the current factory which will make it simple to move the current stuff to the new location.

![Figure 2: Boksburg Current Liquids factory](image-url)
3 Expected Project Outcomes

First Outcome

The first expected outcome of the project is to work with planning and supply management to map the incoming supply chain for each raw and packaging material. The aim is to clearly map the location of the supplier, the and to state the reliability/risk factor associated with the supplier. Any supplier owned storage which can help us to minimise on site storage, minimum storage required for each raw material to ensure sustained supply to the factory. This will also include bulk raw material and the management of trucks on site. An output will be a detailed plan for Raw Material (RM) and Packaging Material (PM) storage as well as holding required to ensure the RM and PM warehouse and bulk tanks are correctly sized.

Second Outcome

The second outcome is detailing the flow of RM and PM into the factory to optimise the flow layout and ergonomics within the factory. To do this an Interface with Planning/Production/Process is required, in order to map out the flow of each raw material to each processing plant/packing plant. Included in the second outcome is to determine where line or side/mixer side storage is required and specify the amount of space required. The idea is to have a complete map for each raw material from supplier to point of use in the factory and to understand the holding requirements at each location with the aim of minimising stock holding while ensuring 100 % availability of material. Optimise the layout of the factory to ensure the most efficient flow of RM and PM throughout the entire process.

Third Outcome

The third and final outcome is to detail the flow of packed finished goods (FG) through palletising, into the onsite FG warehouse and finally through to DHL at Jozi Park (which is located next door to the current factory – An investigation will have to be done to check the best option for transferring FG to DHL). To ensure ergonomic, efficient flow and the correct sizing and layout of the FG warehouse.
4 Interim Report findings summary and review

This section will concentrate on recapping on the conclusions made from the interim report which was the first section phase of the project. As was stated in the interim report, the project approach was to understand the structure of the plant from to bottom. The following subsections are a summary of the suggestions made during phase one of the project

4.1 Purchasing Extra piece of land

As high investments have put in the facility design it is very critical that every decision be evaluated properly before its acted upon, a suggestion was made to purchase an extra piece of land to modify the shape of the land to be square, the suggestion was investigated; the following table summarises the supporting reasoning which supports the buying of the land. The tree diagram which was to motivate changing the shape of the site is included in the appendix.

<table>
<thead>
<tr>
<th>#</th>
<th>Area</th>
<th>Location</th>
<th>Advantage</th>
<th>Disadvantage</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extra portion of land (10,000 m²)</td>
<td>SW boundary</td>
<td>Additional site access; Allows maximum utilisation of land for future expansion</td>
<td>Additional initial CAPEX required</td>
<td>Best opportunity to acquire land &amp; re-zone according to Waterfall requirements.</td>
</tr>
<tr>
<td>2</td>
<td>Staff entrance/ alternative entrance</td>
<td>SW corner</td>
<td>Separates staff and visitors from truck traffic; Reduces traffic congestion on Francis Road; Extra entrance can be used to separate construction traffic from site traffic for future expansion</td>
<td>Additional security monitoring required</td>
<td>Operational advantages outweigh additional security monitoring</td>
</tr>
<tr>
<td>3</td>
<td>Truck entrance</td>
<td>Eastern boundary</td>
<td>Allows truck staging/entering on a private road, thus no council objections</td>
<td>Possible congestion of Jozi Park</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Car park</td>
<td>Southern boundary</td>
<td>Separates car traffic from operational plant area; Likelihood change of location limited as area not proposed for future plans; Flexible enough to allow access from Francis road if required; During construction car park will have a low impact, allowing existing buildings to be demolished as late as possible</td>
<td></td>
<td>See advantages</td>
</tr>
<tr>
<td>5</td>
<td>Rain water harvesting and waste water treatment</td>
<td>SE corner</td>
<td>Lowest point within site, therefore gravity feed opportunity; Overflow of rwh and if required overflow can go into attenuation dam</td>
<td>Treated water needs to be pumped back to the plant</td>
<td>The usable area in SE corner fits the current size requirements. This area has limited use for the main plant area due to its location/size</td>
</tr>
<tr>
<td>6</td>
<td>Truck park waiting area</td>
<td>SE boundary</td>
<td>Next to main truck entrance</td>
<td>See advantage</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Tank Farm</td>
<td>Northern boundary</td>
<td>Located at highest point within the site; Offloading area is along the entire length of the tank farm (flexible offloading conditions); Within close proximity of the porous plant; Allows linear future expansion (E to W); Lower risk of impacting the plant with respect to fire and spillages</td>
<td>It's not the closest position to the process plant;</td>
<td>With the current tank farm size requirements, it cannot be placed closer to the process plant without: i) Splitting between current location and NE corner of building; ii) Split levels on eastern edge of building which will cause additional area to be used for truck turning due to the gradient of the road to the RM/PM store (road at different level to tank farm offloading road)</td>
</tr>
<tr>
<td>8</td>
<td>Utility</td>
<td>NW corner of plant</td>
<td>Centrally located for future PC expansion (shared utilities)</td>
<td>Not optimal for current HCL phase (can be centrally located closest to HCL point of use)</td>
<td>Decision was made in light of future PC expansion</td>
</tr>
</tbody>
</table>
4.2 Layout Options

Three Layouts were generated and one was selected using the Analytical Hierarchy Process, an industrial analysis technique (refer to appendix A). From the results of the analysis the third layout came out as best option with the following criterions in consideration:

- Work flow
- Efficiency
- Flexibility
- Safety

![Layout 1](image1)

![Layout 2](image2)

![Alternative Layouts](image3)

After an evaluation was made by management the second layout proved to be the option that they prefer due to the reason that will be explained in the coming section on the packaging process.
5 Literature Review

General

Companies are constantly trying to find ways to improve performance and warehouse operations. This is an area where supply chain managers can focus on to gain maximum efficiency for minimum cost. To get the most out of the operation, a number of best practices can be adopted to improve productivity and overall customer satisfaction. Although best practices vary from industry to industry and by the products shipped, there are a number of best practices that can be applied to most companies.

When considering the level of effort involved in warehouse operations, the greatest expenditure of effort is in the picking process. To gain efficiencies in picking, the labour time to pick orders needs to be reduced and this can be achieved in a number of ways. Companies with the most efficient warehouses have the most frequently picked items closest to the shipping areas to minimize picking time. These companies achieve their competitive advantage by constantly reviewing their material requirement and production data to ensure that the items are stored close to the shipping area and are still the most frequently picked.

Warehouse layout is also important in achieving greater efficiencies. Minimizing travel time between picking locations can greatly improve productivity. However, to achieve this increase in efficiency, companies must develop processes to regularly monitor picking travel times and storage locations.

Warehouse operations that still use hard copy pick tickets find that it is not very efficient and prone to human errors. To combat this and to maximize efficiency, world class warehouse operations have adopted technology that is some of today’s most advanced systems. In addition to hand-held RF readers and printers, companies are introducing pick-to-light and voice recognition technology.

In a pick-to-light system, an operator will scan a bar-coded label attached to a box. A digital display located in front of the pick bin will inform the operator of the quantity that they need to pick. By introducing this system, companies can gain significant efficiencies as it is totally paperless and eliminates the errors caused by pick tickets.

Voice picking systems inform the operator of pick instructions through a headset. The pick instructions are sent via RF from the company’s ERP or order management software. The system allows operators to perform pick operations without looking at a computer screen or dealing with paper pick tickets. Many world class warehouse operations have adopted voice picking to complement the pick-to-light systems in place for their fast moving products.

Although many companies will not be able to afford new technologies for picking, we’ve seen here that there are a number of best practices that can be adopted to improve efficiency and reduce cost.

Warehouse Best Practices
By Martin Murray, About.com Guide
Efficient operation

In order to ensure the efficient operation of the warehouse a number of important principles were identified by studying best-practices and industry benchmarks. These principles need to be taken into consideration in the design and operation if the new warehouse.

1. **Profile the material stored in the warehouse.** Identify and monitor the flow of SKUs to ensure that the storage configuration minimises the distance and number movements required.
2. **Analyse the picking methodology.** It is important to ensure that the picking and staging methodology optimises productivity and meets the requirements of production.
3. **Maximise the turnover of crucial equipment.** Understand the process flow of the warehouse to identify the crucial points in the process flow then design the process to optimise these crucial points.
4. **Ensure proper scheduling.** In a warehouse with an 8 hour turnover rate it is important to understand and monitor the requirement scheduling to prevent the build-up of excess materials and possible material shortages.
5. **Create “wheelhouse” zones.** Place fast moving items in the “wheelhouse” (Knee to shoulder height racking) area of the warehouse as far as possible.
6. **Standardise load sizes.** Pack materials in standardised unit loads as far as possible to optimise space utilisation and ease material handling.
7. **Consider automation.** Order pickers spend approximately 60% of their time moving products around. Consider and automated solution, such as conveyance, to reduce their extensive travel time. Multi-level pick towers also save time and are quite innovative.
8. **Understand the technological options.** Plenty of options are available to increase efficiency. These options are designed to provide different levels of increased picking production. The advantages of these systems should however be weighed against the associated costs.

Michael J. Stolarczyk
Kontane Logistics
www.kontanelogistics.com

Picking best practices

The modern warehouse and inventory business is much affected by the sense of immediacy and instant gratification that characterises the age of the modern consumer. Warehouses are faced with a much greater expectation of short turnover rates, cycle times and prompt service delivery than ever before. To deliver on these expectations, warehouse management need to evaluate how picking integrates into the receiving and shipping processes that bookend it and try to optimise the overall process.

Optimising picking will deliver big returns to the operation because picking labour expenses are such a big proportion of the total warehouse costs. Some warehouses can use a single picking method. To truly optimise most operations, however, management may well have to use a combination of picking methods. The following considerations for improving the picking in the warehouse were identified:
1. **The success of picking strategies begins with Putaway.** Efficient picking begins with efficient putaway. The efficient positioning of inventory items on shelves, racks or in stacks, sets up successful picking.

2. **Understand the picking requirements.** The following factors influence the selection of the picking method in the warehouse:
   a. What product or types of products/items are being shipped?
   b. Are the items stored as picking pieces, cases or pallets?
   c. How many orders are expected per day?
   d. How many orders and how many picks comprise a typical order?
   e. How often are individual SKUs included in an order?

3. **Defining the relevant key picking objectives.** In designing a picking operation, think in terms of three key objectives; increasing productivity, increasing accuracy and reducing picking cycle time.

4. **Three Primary Picking Systems.** In selecting a picking system there is no golden rule other than pick the system (or hybrid system) which meets the design requirements.
   a. Piece Picking: For low volumes of many different inventory items.
   b. Case Picking: Case picking works for operations that aren't filling orders with open box picks. A warehouse using case picking usually has fewer product SKUs from which it fills its orders as well as higher picks per SKU.
   c. Pallet Picking: Pallet picking provides a lot of alternatives as far as storage configurations and equipment and the lift trucks/towmotors that pickers will use to retrieve pallet loads.

5. **Select the appropriate picking methods.** There are five common picking methods: basic picking, batch picking, multi-order picking, zone picking and wave picking.

6. **Consider technologies in Picking Operations.** Technologies for consideration include:
   a. Automatic picking machines. (The use of fully automated picking machines is generally restricted to operations combining high volume with high accuracy requirements.)
   b. Automatic storage and retrieval systems. (An expensive, high retrieval system of rows of racking used in both putaway and picking.)
   c. Automated conveyor and sortation systems. (Automated conveyor systems and sortation systems are generally suitable for large-scale piece pick operation.)
   d. Carton flow rack. (Similar to static shelving, except that the shelves are angled downwards, enabling gravity feed to the pick face.)
   e. Carousels. (A system of hanging racks that hold storage bins)
   f. Pick-to-light. (Pick-to-light systems consist of lights and LED displays for each pick location, using software to light the next pick task and display the quantity to pick)
   g. Static shelving. (Most commonly found in piece pick operations, this is best suited for low-volume small parts operations)
   h. Voice and speech recognition. (Increasingly popular for inventory and receiving and has tremendous picking application. Voice directed picking can have a huge impact on increasing productivity and accuracy.)

7. **Ensure proper planning of the picking system.** Understand the present and future design requirements of the warehouse and picking system. Analyse existing data to select and implement the best picking systems and methods. Project future growth and ensure the continued feasibility of the picking system.

An effective picking system must minimise travel time and product handling. Each unnecessary movement or additional distance travelled reduces the efficiency of the picking system and therefore the ware. The simplest solution is to locate products as close as possible to the point of delivery and receiving point.
Picking optimisation isn't a point in time; it is a constant process that requires investment (figuratively and literally) from everyone in the organization. While the technology part is critical—picking systems range from simple racks and shelving, to very complex systems that may incorporate multiple pick methods, and multi-million dollar investments in equipment—so is the human capital.

Best Practices for Picking in Warehouses and Distribution Centers
Kevin Collins
SmartTurn™

5.1 Material handling equipment

5.1.1 Material handling trends in 2012

There are some interesting trends emerging in Materials Handling in 2012. Most of these themes focus on cost drivers but also include the environment.

The major trends across many large brands include:

- Labour cost containment and productivity
- Lowering maintenance costs
- Lowering energy costs

Productivity trends:

1. Engineering Productivity

In the marketplace today, there seems to be increased interest in managing labor cost drivers and increasing productivity. Linde Forklifts claim 22% greater productivity for its sitdown counterbalanced forklift truck, model H25T 392. With its hydrostatic transmission, the 392 series Linde requires no differential and therefore has greater productivity with less downtime.

2. Fleet Management Productivity

Other manufacturers, such as Raymond and Crown, are integrating fleet management technology into their lift trucks with iWarehouse and InfoLink. These fleet management tools allow warehouse managers to track usage of materials handling equipment (MHE) in order to reduce labour costs.

Fleet management systems work by requiring an operator to log into a lift truck before using it. Once logged in, the system tracks start time, end time, breaks, idle time, lifting hours, etc, to generate reports on equipment overall usage. By knowing start and stop times, managers can identify employees who start and stop on time and work their equipment the hardest, which helps increase warehouse productivity. By knowing lifting hours, supervisors can identify the types of equipment needed for any given task. For example, if a reach truck shows low lifting hours relative to travel hours, a manager might decide that a pallet jack is more suitable for certain handling tasks and reduce capital costs in horizontal product transportation.
3. Automated Lift Truck Productivity

Other labour saving innovations include Raymond Corp’s recent announcement of the Courier Automated Lift Truck (ALT). This all-seeing automated pallet truck is taught a route in the warehouse for predetermined pick-up and drop-off points. The operator drives the pallet jack briefly and picks up a pallet on the ALT. He then turns the knob to automatic, picks the drop off point on an on-screen menu, and tells the pallet jack to “go” by pressing a button. Using the vision system, the ALT takes the pallet to the drop off point, possibly from manufacturing to storage or from the dock to an awaiting Narrow Aisle truck working in the racking. The advantage to this truck is it now reduces the labour expense of long tedious and repetitive trips. And with an operator shepherding multiple ALTs at a time, labour savings increases exponentially.

Lower maintenance costs

The message from many of the MHE OEMs (original equipment manufacturers) is that maintenance costs are continuing to be reduced.

Crown Corp uses color-coded wiring and hundreds of fault codes to help quickly pin-point component failures. Crown claims this drives down repair cost by making forklift technicians more efficient. Also, due to their vertical integration and close controls in their manufacturing processes, Crown claims their component failures are more infrequent.

Yale and Hyster announced more durable pallet trucks at ProMat 2011. The improvements to the pallet jack design, includes:

- More rigidity added to the forks by encasing the fork frame.
- Added a fork torsion box to for more stability for the operators.
- Forks can sustain a longer life by the addition with an enclosed toe box.
- High Frequency (HF) charger increase battery life by sensing state of discharge of the battery to prevent overcharging and short life-in the battery.

Raymond Corp announced recently a revamped end-rider pallet truck built with harder steel, replaceable wearable parts in its undercarriage and self-lubricating bushings. In addition, Raymond makes the following claims about their new model 8410 end-rider pallet truck:

- Heavy-duty undercarriage features ductile iron components for longer wear.
- Heavy-duty bumper guard.
- Longer component life with sealed grab bar electronic controls.
- Faster acceleration.
- Low step heights to reduce fatigue.
- Power steering that reduces steer effort by up to 90%.
- Up to 6% more productive than the competition.
- Up to 33% more energy efficient than the competition.

Lower energy costs

One of the main cost drivers in warehousing operations, energy consumption reduction has become the theme for warehouse lighting manufacturers, battery charger manufacturers and lift truck manufacturers.
Did you know that by 2014, you will not be able to buy a light bulb that is 40 watts or greater? This is part of the drive to reduce energy consumption and increase energy efficiency.

Many warehouses are being fitted with high efficiency lighting. And LED lights and induction lighting are now available for freezer warehouses to reduce energy use and reduce maintenance costs. Just look at US Cold Storage who installed LED lights and reduced their energy consumption and energy costs from 46 cents/sq. ft. to 3.5 cents /sq. ft.

And because LED lights have a longer life span, maintenance costs will also be reduced. This is because an LED light fixture can expect up to a 20 year life span before needing to be replaced.

The Raymond Corporation has introduced eco-performance touting increased energy efficiency by 20%. With their regenerative lowering and ACR system, Raymond claims their lift equipment is more energy efficient and returns energy back into the battery when lowering a load and plugging to a stop.

5.2 Forklift power sources

5.2.1 Electric forklift considerations

Information on electric forklifts

1. **Life expectancy for a lift truck’s battery**: Forklift lead acid batteries usually have work life of 1500 cycles or more.

2. **Sealed lead-acid forklift battery**: Maintenance-free batteries are a popular option for use in controlled working environments such as pharmaceutical manufacturing. pallet trucks (electric pallet jacks) as they can operate in any position. The acid inside the battery is made into a gel and sealed inside the cell. Valved cell caps allow for venting during charging. The loss of moisture shortens the life of the maintenance-free battery over time.

3. **Absorbed Glass Mat Batteries (AGM) for forklifts**: German high performance cars us AGM batteries due to their durability and ability to endure extensive shock and vibration. This technology is sealed and maintenance free, however are almost twice the cost of flooded lead-acid batteries. By using absorbed glass mats between the plates, the batteries recombine the oxygen and hydrogen inside the cells and lose almost no water.

Warehouse IQ
www.warehouseiq.com
5.2.2 Gas versus Electric Forklifts

Gas Forklifts

Gas-powered forklifts are designed for outdoor use. They are sturdy and rugged, built to withstand uneven terrain and harsh weather. Much like your car, gas forklifts run on gasoline and need to be serviced regularly to remain in good working condition.

1. Gas Forklift Prices: A standard 2 000kg capacity gas forklift costs anywhere from R120,000 to R240,000. The price varies based on the brand and quality. Larger 4 000kg capacity forklifts can cost up to R360,000.

2. Gas Forklift Pros:
   - Price - Gas forklifts are less expensive upfront than electric models. A gas model costs slightly less than an electric model with the same size and specifications.
   - Versatility - Because gas forklifts are designed for outdoor use, they’re suitable for a wider variety of jobs, tasks and industries. They can be used in construction, landscaping and farming, to name just a few.

3. Gas Forklift Cons:
   - Cost to operate – Gas forklifts have more on-going expenses and required service on a more regular basis than their electric counterparts. Further there’s the cost of fuel, for one, which is not insignificant.
   - Noisy - The engines are noisy, so gas-powered forklifts can create a distraction in quiet areas.
   - Produce emissions - As with any gas-powered vehicle, gas forklifts produce emissions that are harmful to the environment.

Electric Forklifts

Electric forklifts are battery-powered and require regular recharging, usually overnight. Electric forklifts are designed primarily for indoor use, particularly in warehouse and other industrial facilities.

1. Electric Forklift Prices: A standard 2 000kg capacity electric forklift costs R160,000 to R240,000, depending on brand and quality. In some cases, you might have to pay up to R40,000 extra for a battery and charger.

2. Electric Forklift Pros:
   - Cheaper to operate - Electric forklifts require no fuel and very little maintenance. The batteries are rechargeable and replaceable.
   - Longer lifespan - Electric forklifts typically last longer before major components start to fail. In some cases, the lifespan of an electric forklift is nearly double.
   - Eco-friendly - Electric forklifts do not produce harmful emissions.

3. Electric Forklift Cons:
   - Price - Despite the money you'll save on fuel and maintenance in the long term, you'll have to shell out more cash upfront to purchase an electric forklift.
   - Not suitable for outdoor use - Electric forklifts can be easily damaged if exposed to the elements.
   - Require charging - Most batteries need about eight hours of charging for the forklift to be operational for a full day. Unlike gas forklifts, electric forklifts are not always available when you need them.
5.2.3 Hydrogen forklifts
Fuel cells have been heralded as the green solution to cars. Much money has been invested into research and development for making the technology work in the car market, reducing emissions and making the air we breathe cleaner. While scientists are working on putting the technology into the car market, new companies have also emerged looking into building fuel cell for forklifts. Some problem however remains with this technology:

1. Emissions and Air Quality: Fuel cells, like batteries, contribute no harmful emissions. In fact, they produce only water vapour which is absorbed by the warehouse air and or stored in a reservoir that gets removed during a fuelling event. But the sourcing of hydrogen for the fuel cell is less straight forward. Hydrogen must first be produced from reforming natural gas, a process that separates the hydrogen gas using steam. This process produces more CO2 into the atmosphere than simply burning the gas would. So the environmental claims for fuel cells are no completely straight forward.

2. Fuel Costs: Hydrogen is not cheap. When you think about hydrogen fuel cells, you might think the fuel is competitive with the cost of propane or electricity. However, for equivalent work, the fuel cell will cost you twice for fuel over the price of electric going into a battery.

3. Equipment Costs: Another problem that fuel cells might solve is the cost of batteries for forklifts. Batteries continue to rise in costs and represent, with chargers, a large investment for the fuelling of forklift trucks. The problem is that fuel cells are expensive also. They are roughly the price of 3 batteries each, but are estimated to have a useful operational life of 10 years – longer than the estimated useful life of a forklift battery. Also, whereas a Ferro-resonant battery charger costs roughly R16 000, the infrastructure to refuel a fuel cell is anywhere from R2,400,000 to R8,000,000. Assuming 3 shifts at $2,000 per forklift charger, there would need to be 75 forklifts to equal the cost of hydrogen refuelling infrastructure costs.

5.3 Forklift types
An investigation of the specific forklifts available for the warehouse yielded the following results in terms of forklift types and makes. This is not the final list for consideration but merely an indication of the alternatives on offer.

5.3.1 Hand operated forklifts
Hand pallet trucks:

1. ST3000
   • Full-function control handle with neutral, hydraulic unit proven reliability, strong fork design, durable frame and articulating wheels, easy pallet entry and exit and long-term value. (By Crown forklifts)
Power pallet trucks:

2. WT 3000
   - The WT 3000 offers the widest model variation available including four platform configurations, capacities of up to 3 tons and electronic steering. Includes: FlexRide™ operator suspension, e-GEN™ braking system, Access 123® control system, Entry Bar Safety Switch and quick-exit side restraints. (By Crown forklifts)

Stackers:

3. ST 3000
   - The ST 3000 Stacker Series was engineered to deliver the same level of durability, reliability and ease of use as the largest heavy-duty stackers and is backed with a lifetime chassis warranty. Adjustable forged forks and adjustable outriggers provide the flexibility to keep pace with business and product changes. The unique X10® handle and SEM traction system deliver precision control. (By Crown forklifts)

5.3.2 High-level forklifts
Reach trucks: RR 5200

   - The Crown RR 5200 delivers the best performance in the reach truck industry for travel and lift/lower functions. Crown's Comprehensive System Control with Access 123® technology provides the operator and service team with the most comprehensive diagnostics in the industry. (By Crown forklifts)

5.3.3 Heavy duty forklifts
Electric counter balance trucks:

1. Doosan
   - Counter balanced trucks are the workhorses of the industry, driven hard every day. Includes: full AC control, Gechnology (Hyd., Drive), optimised operator comfort and safety and faster travel and lift speeds. (By Doosan forklifts)

5.3.4 Narrow isle trucks
Turret trucks:

1. TSP 6000
   - The TSP 6000 Series offers the versatility to handle a wide range of warehousing challenges from full pallet put-away and picking to transporting and staging. Operating in aisles only slightly wider than the truck itself, the TSP 6000 Series can lift to 11.7 m with a maximum capacity of 1250 kg.
Articulated trucks:

1. B 315 AC
   - Designed to give optimum aisle performance. Can store in 1.5m aisles and enable storage density exceeding very narrow aisle (VNA) installation. (By Bendi forklifts)

Source: Goscor lift truck company.

5.3.5 Forklift type comparison

Counterweight trucks:

Standard forklifts mainly used in warehousing and material movement. The counterweight truck is the workhorse of the warehousing industry. The main advantages of this type of forklift are its rugged design, its low maintenance cost and its ability to transport materials over long distances. Its disadvantages include its limited capability of 6m high storage, increased aisle width requirements and its lack of flexibility.

Turret trucks:

Turrets trucks lift the forklift operator up with the level of picking enabling increased accuracy and control. The forklift is also able to operate in very narrow aisles and operates at a higher level of productivity than most forklifts (32+ pallets per hour). The disadvantages of this forklift is that it isn’t suited for unloading or transportation on goods, it is expensive to procure and maintain and it can only operate on perfectly flat surfaces.

Reach trucks:

Reach trucks are forklifts specifically designed to store at greater height and in aisle of a smaller width than conventional forklifts. Reach trucks provide the ability to store at higher levels using narrow aisles. However reach trucks tend to cause increased material handling damage and decrease productivity by storing goods out of the clear view of the operator as well as being more expensive than conventional forklifts.

Articulated trucks:

Articulated trucks are designed as a replacement to the reach trucks. The main advantages of the articulated trucks are its increased productivity, decreased material handling damage and increase functionality in terms of capability to perform other functions such as unloading. The articulated trucks are however expensive to procure and maintain.

5.4 Automated storage

Advantages:

- Fully automatic storage.
- Increased height limit, up to 41m.
- Improved storage capacity in a reduced footprint.
- Payload capacities up to 1,500 kg.
- Single, double, and satellite storage configurations.
- Latest control technologies.
Disadvantages:

- Expensive.
- Complex.
- Difficult to implement.
- Error-prone.

5.5 Storage equipment

5.5.1 Racking options

Universal storage systems provides the following pallet racking options as an example of the types of racking to be considered:

1. Uni-Rack: Adjustable pallet racking:
   - Ambient and coldroom pallet racking – consumer goods; paper; timber; chemicals; heavy components and parts and many other uses.

2. Uni-drive: High Density Pallet Racking:

3. Uni-Pushback – Pushback Pallet Racking:
   - Interlinked trolleys that run on an inclined track within a track.

4. Uni-Shuttle: Motorised Pallet Racking:
   - A shuttle system consists of supporting rack, shuttle rails and a shuttle cart. The shuttle cart runs on the rails and in propelled by an electric motor. It has a platform on the top that can lift up and down.

Other racking options include:

5. GlideRack; Mobile Racking for increased selectivity:
   - GlideRack is Mobile Racking. Mobile racking is designed to move. This system is designed to give slower moving items the opportunity for high capacity storage.
   - Prior to GlideRack an aisle was required for every two rows. Now with GlideRack 1 aisle is required per every 4-20 rows of single selective racking.

5.6 Conclusion on Literature Review

After consideration of the information indicated in this document a number of key considerations were identified.
5.7 Key inbound considerations

Warehousing best-practice regularly point to modern technology to increase picking efficiency and accuracy. However due to the fast turnover and low material variation of goods stored in the warehouse these technological advances promise little benefit to the particular warehouse and the cost associated therefore remains unwarranted.

A critical success factor of the warehouse would be the proper planning and scheduling of the arrival of goods according to the production schedule. Inaccurate scheduling would lead to build-up of excess goods, directly impacting the productivity and utilisation in the warehouse.

The proper layout design of the warehouse to minimise the travel distance of materials is an important factor. The layout design also needs to be effectively implemented and enforced to reap the maximum benefit from layout design advantages.

The procurement of the required forklifts for the warehouse is a crucial part of the development of an efficient warehouse. The cost, reliability, maintenance costs and storage implication are some of the important consideration to take into account.

In terms of types of forklifts, gas forklifts seem to outperform electric forklifts with regards to the specific requirements of this warehouse. Two material handling processes are also available for consideration.

1. The use of conventional forklifts to load and unload trucks and specialised forklifts to store and retrieve goods.
   - Smaller aisles.
   - Higher stacking ability.
   - More expensive.
2. Only using conventional forklifts to unload and store pallets.
   - Wider aisles required.
   - Less expensive.

Other racking options should be considered, although pallet racking should provide an inexpensive effective racking solution.

Automation is deemed too expensive and required extensive implementation and skills to operate. It is therefore excluded and a feasible option.

It is also important to take the environmental impact into account when designing the lighting and layout of the warehouse.

5.8 Key outbound considerations

Since the outbound warehouse mainly acts as an accumulation area in preparation for transportation the recommendation is to keep the process as basic as possible.
6 Design Approach

The project was done using a top down approach while implementing industrial and systems engineering techniques to first understand the needs or expected outcomes of the project then further understanding the functional requirements of the facility. The main design strategy that was used in the project is a top-down approach which is used for designing lean storage for equipment. The lean storage method first analyses the global view or design of the project, which is when the plot selection criterions are stated and the available plots are weighed and the most suitable layout is selected.

After the global design follows the Supra-level of the design, this is when the different departments are allocated to different areas in the plot. A relationship chart was used to allocate the different departments and the optimal layout was chosen. The first two stages of the lean storage design were covered in the first phase of the project.

This project will focus on the macro design where the factory design will be broken down to three separate design sections starting with the inbound, process and outbound respectively. The inbound was analysed by tracing all the inbound process, functionality, space and material handling equipment. The process was first described then a co-ordinate method was developed to mark the location of the machinery on the packaging area. The making of the products in the factory is illustrated using a flow chart for the making of Handy Andy. The design of the outbound warehouse will not be dealt with in depth in the project since it is controlled by a third party meaning the layouts and configurations are designed by DHL (third party).

To facilitate the design improvement process the systems engineering method was used over the systems life cycle model. The table below summarises the activities involved in each design stage during the implementation of the improvement method.

Table 1: Systems Engineering Method over life cycle model

<table>
<thead>
<tr>
<th>Step</th>
<th>Concept Development</th>
<th>Engineering Development</th>
<th>Integration and Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Needs Analysis</td>
<td>Concept Exploration</td>
<td>Concept Definition</td>
</tr>
<tr>
<td>Requirements analysis</td>
<td>Analyze needs</td>
<td>Analyse operational requirements</td>
<td>Analyse performance requirements</td>
</tr>
<tr>
<td>Functional Definition</td>
<td>Define system objectives</td>
<td>Define subsystem functions</td>
<td>Develop functional architecture component functions</td>
</tr>
<tr>
<td>Physical Design</td>
<td>Define system capabilities</td>
<td>Define system components, visualise components</td>
<td>Develop physical architecture components</td>
</tr>
<tr>
<td>Design Validation</td>
<td>Validate needs and feasibility</td>
<td>Validate operational requirements</td>
<td>Evaluate physical possibilities</td>
</tr>
</tbody>
</table>
7 Inbound Material Flow

To facilitate communication within the design team it is always recommended to use diagrams that show the material and information flows. The first version of the flow diagram for the inbound raw and packaging material has been captured and documented below.

![Inbound Material Flow Diagram]

**Figure: Inbound flow process**
7.1.1.1 Flow diagram correction and description
After the team reviewed the work flow a few changes had to be done as follows:

Production planners: all they would do is plan production.

Material planners: After production planner plans material planner would check availability of materials on the system, establish if material on hand is within targeted/required level, and then the rest of the flows we have under material planner will follow.

Production Operator: Generate pull list – this would be the first step -

Stores: Receive pull list > check availability of material requested > locate materials > pick material > stage materials

The summary for the flow of material to the packaging area is as follows:

When a truck driver arrives to deliver material, it passes through the security gate for weighing and security checking. If the truck passes the test it then drives to the unloading dock where the truck driver is required to provide the required paperwork and wait for the folk lift to come unload material,

The folk lift comes to the unloading docks to take the delivered material to it location in the warehouse where they are stored in racks that are three levels high. Before the material is delivered to rack they are first staged close to the unloading area. The production planners release their production plan to the material planers and they then check the availability of the material in the warehouse and compare it to the required inventory.
After the flow diagram was compiled a more detailed step by step analysis of the inbound material flow was constructed and will be shown as follows:
1) Vehicle manoeuvring

Trucks arrive from the main warehouse to deliver material and the first action that can be identified when a vehicle arrives for delivering material is the manoeuvring action which is when the driver tries to position the vehicle in the optimal position for the off-loading of material from the trailer.

2) Off loading

After the driver has managed to position the truck in a position that allows the fork lift to effectively reach and collect material from the truck, the material is taken off from the side of the truck one pallet at a time depending on the number of available forklifts.

3) Accumulation

The third notable action that needs to be performed during and after off-loading is staging of the pallets in the accumulation designated area. This area will serve as space to accumulate a specified number of pallets. This action is an optional requirement which could be avoided but was not possible to avoid in the making process.

4) Placing in Storage

The key action in the delivering of material is to place material in a dedicated or random rack and after the material has been kept in the accumulation area they are ready to be taken to the area where they will be stored until the time when they are delivered to the place of use.
5) Storage

The material is then stored and retrieved from the racks depending on the requirements for the shift the material is picked and delivered. The storage policy for the staging warehouse would be for two 8 hour shifts. The design will use a racking system based on simulated times to show which option will be optimal with speed as the main design attribute.

6) Picking

A folk-lift will come and collect the pallets from the storage area when it is required.

7) Staging

Staging in this context refers to the temporary location of the material before they are put to use. The staging area normally holds approximately one to two pallets of inventory for most material with the extreme exclusion of the bottle pallets which require more inventories.

8) Feed Production Line

This step can be recognised as the last stem in tracing the inflow of raw and packaging material.

figure: Inbound flow flow analysis
Inbound process flow

The following is an illustration of the expected process flow for the inbound material warehouse.

Figure: Actions for inbound flow

The following assumptions where made in determining the design requirements for each area and activity in the process:

1) Truck parking
   - Parking/unloading bays for 4 trucks are available for simultaneous unloading.
   - Trucks arrive at the inbound warehouse over a 23 hour period at an average rate of 2.975 trucks/hour with peak times between 10:00 and 12:00.
   - The truck arrival rate is calculated based on the estimated material flow and not the maximum material flow.
   - The truck arrival rate is calculated as follows:

Table 2: Truck Arrival Rate

<table>
<thead>
<tr>
<th>Material</th>
<th>Total pallets/12hours</th>
<th>Total pallets/day</th>
<th>Pallets/truck</th>
<th>Trucks</th>
<th>Trucks/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC's</td>
<td>133</td>
<td>255</td>
<td>48</td>
<td>5.3</td>
<td>0.231</td>
</tr>
<tr>
<td>Bottles</td>
<td>544</td>
<td>1043</td>
<td>26</td>
<td>40.1</td>
<td>1.744</td>
</tr>
<tr>
<td>Caps</td>
<td>38</td>
<td>73</td>
<td>26</td>
<td>2.8</td>
<td>0.122</td>
</tr>
<tr>
<td>Dividers</td>
<td>22</td>
<td>43</td>
<td>26</td>
<td>1.7</td>
<td>0.072</td>
</tr>
<tr>
<td>Pouches</td>
<td>40</td>
<td>77</td>
<td>26</td>
<td>3.0</td>
<td>0.129</td>
</tr>
<tr>
<td>Other</td>
<td>121</td>
<td>232</td>
<td>26</td>
<td>8.9</td>
<td>0.388</td>
</tr>
<tr>
<td>Raw mats</td>
<td>173</td>
<td></td>
<td>26</td>
<td>6.7</td>
<td>0.289</td>
</tr>
<tr>
<td>Total</td>
<td>68.4</td>
<td></td>
<td>2.975</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2) Accumulation
   - Pallets in accumulation are stacked up to 1 level high.
   - Space is allowed for 100 pallets in the accumulation area, totalling two 26 pallet trucks and one 48 pallet truck.

3) Storage
   - The size of pallets is assumed to be 1.0m by 1.2m;
   - Initial stacking regulations is defined as:
     i. 2 for finished goods.
     ii. 2 for empty bottles.
     iii. 2 for returnable packaging.
     iv. 2 for Caps
   - The following materials are to be placed in racks:
     i. CC’s 3 high.
     ii. Raw materials 3 high.
   - An additional safety margin of 40% is added to packaging material stock to compensate for assumptions made during flow calculations.
   - Other packaging materials such as labels and shrink-wrapping is accepted to be 15% of the total packaging material requirements.

4) Staging
   - No additional staging equipment is required.
   - Staging space should equal the space required to place 1 hours’ worth of bottles and caps stacked 1 level high.
   - All other materials will be stocked outside of the main storage area.
   - Products are all delivered by forklifts to the staging area and then delivered to the packing lines by automatically or by hand.

a) Offloading
   - Trucks will be offloaded by forklifts.
   - A forklift takes on average 3 minutes to unload a pallet from a truck.

b) Placing in storage
   - Pallets will be transported to allocated marked slots according to the type of material.
   - Materials will be placed in storage by forklifts.
   - The travel time for forklifts to store materials is assumed to be:
     i. 7 minutes for Bottle pallets to hand Andy Packaging staging
     ii. Xs for material Y to line Z
     iii. etc.

c) Picking
   - All pallets will be transported to the staging area by forklifts.
   - The travel time for forklifts to pick materials is assumed to be:
     i. 7 minutes for Bottle pallets to hand Andy Packaging staging
     ii. Xs for material Y to line Z
     iii. etc.

d) Feeding production
   - Materials will be fed into the production lines from the staging area by hand.

e) Return packaging and partial pallets
• Partial pallets are returned to storage.
• 1002 empty pallets are to be returned per shift and are handled in bundles of 10 and stored by stacking bundles to 2 levels high based on the estimated material requirements.
• 38 trays are to be returned per shift and are handled in bundles of 100 and stored by stacking bundles to 1 level.
• 544 cartons are to be returned per shift and are handled in bundles of 100 and stored by stacking bundles to 1 level.
• Cartons and lids are assumed as one unit and returned together.
• Space is provided for 8 hours’ worth of returnable pallets.
• Space is provided for 8 hours of trays.
• Space is provided for 8 hours of cartons.

f) Loading returnable packaging and excess materials

• Returnable packaging and excess goods are loaded onto the same trucks that deliver materials.
• 100 pallets (10% of the estimate) of excess goods are loaded for return per shift.
• 1002 returnable pallets require loading per shift.
• 1 pallet of trays require loading per shift.
• 11 pallets of cartons require loading per shift.
7.1.1.2 Overview of the inbound flow

Figure 4: Combined inbound flow analysis

The diagram summarises the material the steps involved it shows all the inputs and outputs of the steps in the inbound. The diagram also shows the physical and functional requirements for each of the steps.
8 Systems Dynamics Factory model

In order to respond to the problem of the unstable demand of the market and the uncertain issues surrounding the expected levels of inventory that should be kept in the warehouse, a systems dynamics model will be developed. This model will be customized for Unilever to use on any of their factories. The model will be based on the Waterfall project. The model will attempt and include everything that is necessary for production.

The model below is a rough sample of a model similar to the one that the model that will be developed. It is a model that illustrates the causal relationships that are found in a factory.

![Figure 5: Systems Engineering Model](image)

The model will have some simple characteristics of the similar to the preceding model. The main goal of the model is to address any issues that are needed in the decision making process when addressing the production and storage design constraints. It will help simulate the decisions made in a simpler manner to avoid the elongated waiting periods when developing software intense simulation models.
8.1 Modelling approach

The flow chart below shows the steps that are followed when developing in designing a successful systems dynamics model. The first step which is to determine the simulation parameters will be determined using industrial engineering techniques and the second step which is to determine the ranges for the parameters and distributions will be estimated using data that was collected through informal time and motion studies thereafter statistical functions will be used to in conjunction with the random function from the excel functions.

Different simulation results will be generated by allowing different production scenarios:

Different simulation results will be generated by implementing different production and varying order sizes and also includes unexpected variation induced by machine failures and worker absenteeism.

![Diagram](image)

**Figure 6: Simulation approach**
8.2 Analysis parameters of the model

The model will be based on the production sector model but will be altered to exclude some and excludes some of the factors included in the model and also include the production process steps in order to highlight the amount of material used per machine and to indicate how much waste is produced in production.

Figure 7: Causal relationship diagram

The above diagram above shows the causal relationship model in the factory model. The following diagram is a modified version of the model above. It has been modified to be used in analysing the production and processing line of the handy Andy product line.

Figure 8: Stock and flow diagram

The simulation model depicted by the excel derived stock and flow diagram will be included in the appendix. The model shows the inputs and output processes and steps of the packaging and processing material.
8.3 Inventory Calculations

Designing a warehouse for a fast paced manufacturing firm requires intense understanding of the expected inventory levels and is greatly affect by the fact that different variants are being produced in the factory. The approximation or calculation of the inventory will be based on the systems dynamics model that was developed to analyse the system. The model aims to simulate the maximum rack space and pallet space required. The inventory space requirements will be shown using graphs that were extracted from the systems dynamics model.

8.3.1 Loading bay space requirement for white bottles

The following graphs represent the estimated expected number of bottle pallets that will be available at every hour during production. The time is in hours and each shifts lasts 12 hours. The consumption of bottles is dependent on which variant is being produced. The first graph is for the white bottles, which is used in the majority of the variants produced and in the second graph are the lavender bottles which are used in the Lavender variant.

![White bottle inventory graph](image)

**Figure 9: White bottle inventory**

8.3.1.1 Analysing the results:

White bottles used to package handy Andy are consumed more than bottles of any other colour. The graph simulating the expected inventory levels for Handy Andy. Production is simulated for a period of 197 hours. The constant drops and rising in the graphs shows the consumption and refilling of the inventory with the horizontal steps showing a period when the inventory was not being consumed either because a variant requiring a different coloured bottle was used or production had stopped due to mechanical failures and maintenance.
8.3.2 Loading bay space requirement for Lavender Bottle inventory

The graph shows the behaviour of the inventory under the assumption that two truck load (64 x2) of 128 pallets is delivered when inventory levels reach 30 pallets.

The graph shows the inventory levels with the assumption that a truck load of 64 pallets are delivered when inventory level is less than 10 pallets.

8.3.2.1 Analysis of results:

The graph shows that when production runs for 77 hours allowing for breakdowns variant changes, the maximum pallets of lavender bottles would be in the warehouse is 75 pallets. That means that lavender bottles for Handy Andy can be allocated a bay storage space of 80 bottles stacked two pallets high, meaning 40 loading bay space.
8.3.3 Rack space requirement
This graph which is similar to the preceding graphs shows the inventories of hand Andy caps and the wrapping plastic.

![Graph showing inventories of hand Andy caps and wrapping plastic]

Figure 11: Wrapping Plastic and Caps inventory
8.3.4 Packaging Cases Inventory

The graph below represents the expected inventory levels for the casing boxes inventory, the complication with this graph is that each variant has its own box with different labels. Handy Andy has six variants and each has a different casing.

![Cases Inventory Graph](image)

Not all variants are included in the graphs; the variants will all be included when summing the total amount of pallets that will be in the warehouse.

8.3.4.1 Analysis of Results

The graph shows that the inventory of the boxes is highly sensitive to the change in the variants being produced in the Handy Andy line. This is caused by that each variant has to be packaged in a specific box. From the graph it would be reasonable to conclude that having a minimum stock of ten pallets per variant would be reasonable safety stock.
8.3.5 Raw Material Inventory

The graph below shows the estimation of raw material inventories (in pallets) for raw material used in Handy Andy. The assumption is that the material will be used for two shifts.

![Graph showing raw material inventories per hour](image)

**Figure 13: Raw material inventory**

The values in the graph were first obtained by consulting with the people in the stores and then later recalculated with the actual consumption of the material at the process making. The total number of racks that is required for the storage of raw material is shown below.

![Graph showing total raw material pallets inventory per hour](image)

**Figure 14: Total raw material inventory**
8.3.6 Total Number of Pallets in the warehouse

The graph below shows the average number of expected pallets that will be in the warehouse for duration of 40 shifts. The graph does not include the pallets for Bottles as it assumed that they will be stored in bays as compared to other material which will be stored in the racks. The graph does not represent the number of racks required since some of the racks accommodate two pallets. Also what is to be noted is that the some of the packaging materials are not included in the graph.

![Total number of H/A pallets per hour](image)

*Figure 15: Total material inventory*

8.3.7 Analysis of the results

With material used in the Handy Andy production line included in the calculation for the total number of pallets space required in the warehouse, a total of 135 racks seem to the best number of racks that can be allocated to the handy Andy production line. For safety purposes it would better to state that 170 rack space need to be allocate for the storing raw and packaging material in the Handy Andy production line.
8.3.8 Empty pallets and waste management
With a schedule of an accumulation of 200 pallets inventory before the trucks are taken by truck the following graph was generated to investigate the behaviour of the empty pallet inventory. The graph was constructed using the pallets that are consumed in the Handy Andy making and packing processes.

![Diagram of Empty Pallet Inventory](image)

**Figure 16: Empty Pallet Inventory**

8.3.9 Analysis of results

It can be seen that with the Handy Andy production line producing an average of 210 pallets per two shifts it is reasonable to allocate a pallet storage of 250 pallets per production line since the consumption rate of pallets in the production lines does not differ by a large degree.
8.4 Warehouse layout options

After the expected inventory levels have been estimated using systems dynamics and the routings of the workflow had been designed it is time to check for the layout that best improves the flow of the material in the warehouse. The flow is greatly impacted by the amount of material being handled, the space in between the isles, the distance from the unloading dock to the place of use.

In designing the warehouse the storage design considerations are as follows:

8.4.1 Storage design considerations
- Maximise space utilization
- Maximize equipment utilization
- Maximize labour utilization
- Protection of all materials

8.4.2 Requirements for receiving
1. Sufficient area to stage and spot carriers – area for reception, waiting, parking and manoeuvring of vehicles.
2. Docks to facilitate carrier unloading
3. Sufficient area to palletise or containerise goods
4. Sufficient area for inspection of goods
5. Sufficient area to place goods prior to dispatching
6. An office to house information on purchase prior to dispatching.
- In the designing of the warehouse

8.4.3 The block layout

The block layout has been in use in the warehouses for a long time and has shown to have sustained advantages over its competing layout configurations. For the project the project, the normal block layout will be the first option but another layout will be suggested as will be seen later in the text.
8.4.4 The proposed warehouse layout

The following diagram illustrates a warehouse configuration that needs has been proven by research to have an advantage over the basic block layout. The layout is called the fishbone layout for its V-shaped diagonal crosses and horizontal and vertical intersections of the isles.

![Diagram of fishbone warehouse layout](image)

Figure 17: Original Fishbone Warehouse Layout

The warehouse layout has an advantage in that it maximizes the distribution rate of the material that needs to be stored the limit to design in the application of the project is that it does not offer space for loading bays which will be used to store bottle pallets. Since the bottles are stacked two pallets high they will not be able to sit well in the racks therefore an alternative which can accommodate the both the loading bays and the racks had to be formulated.