UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

DEPARTEMENT BEDRYFS- EN SISTEEMINGENIEURSWESE
DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

FRONT PAGE FOR FINAL PROJECT DOCUMENT (BPJ 420) - 2010

Information with regards to the mini-dissertation	
Title	Analysis for Enhanced Performance of a Warehouse Outbound Planning Process
Author	Schoeman, C.C.
Student number	27129439
Supervisor	Adetunji, O.
Date	10/05/2010
Keywords	Outbound planning process, Barloworld logistics, Nike, Warehouse, Order picking, Wave planning, Wave picking
Abstract	The project is based on analysing and improving the outbound planning process, especially focussing on an order picking technique known as wave planning/picking, of a Nike warehouse in conjunction with the company Barloworld Logistics.
Category	Logistics

Declaration

1. I understand what plagiarism is and I am aware of the University's policy in this regard.
2. I declare that this is my own original work
3. Where other people's work has been used (either from a printed source, internet or any other source) this has been carefully acknowledged and referenced in accordance with departmental requirements
4. I have not used another student's past work to hand in as my own
5. I have not allowed and will not allow, anyone to copy my work with the intention of handing it in as his/her own work

Handtekening **Signature**	

Analysis for Enhanced Performance of a Warehouse Outbound Planning Process

by

CC SCHOEMAN
27129439

Study Leader: Mr Olufemi Adetunji

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

August 2010

EXECUTIVE SUMMARY

The following report details the completion of a final year project required for a Bachelors of Industrial Engineering at the University of Pretoria.

The project was completed at a Nike warehouse managed by the company Barloworld Logistics. The assignment is based on analysing and improving the outbound planning process of the warehouse and more specifically a warehouse management and order picking technique known as *wave planning* or *wave picking*, which is thoroughly explained in this document. The fundamental tasks that were required to complete the final project included: gaining a thorough understanding of the Nike warehouse daily outbound planning operation, researching industry tools and best practices that could be used to optimise wave planning through a literature review, analysing historical data of the average orders completed on a daily basis, determining possible wave planning improvement solutions specifically for the Nike warehouse, testing the proposed wave planning solutions through simulation and finally selecting and testing the preferred theories in practice.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION AND BACKGROUND

1.1 COMPANY BACKGROUND

Barloworld Logistics is a division of the global industrial brand management company *Barloworld*. The company is a market leader in the provision of integrated solutions in distribution, rental, fleet management, product support and logistics to a wide variety of customers. One of these customers is the Nike warehouse located in Isando, Johannesburg. Barloworld Logistics runs the day-to-day affairs of the warehouse; managing inventory, inbound and outbound processes and all related activities. The warehouse is highly efficient handling approximately one million orders a month, the equivalent of 48 000 orders a day. However, the operation still faces obstacles which impede productivity, one of these being the optimality of the outbound planning process.

1.2 PROBLEM BACKGROUND

A conventional warehouse order picking technique frequently used in the industry is that of *wave planning*, also known as *wave picking*. Wave planning is a term used to describe a process, within a warehouse management system, which supports and simplifies the daily work of managing picking and packing activities and other related tasks. The daily workload is divided into a series of relatively comparable intervals known as waves, which are then released according to a schedule, often an hour apart. Waves are defined according to a vast array of criteria such as urgent orders, orders destined for similar locations, orders going via similar routes, material handling requirements or according to function i.e. the tasks triggered by the release of a wave, such as full case picking, fine picking, value added services, replenishment or packing.

The basic concept works as follows; picking workers must pick inventory and deliver these picks to the packers before packing can commence. The packers must pack before the loaders can load and so forth. Thus these picks are divided into waves. For example, after wave 1 is delivered to packing, wave 2 is picked while wave 1 is packed and subsequently wave 1 is loaded while wave 2 is being packed. This promotes continuous flow and consequently improves efficiency.

There are two basic planning elements to wave planning:

- The sequence of orders and assignment to waves; and
- Assigning floor personnel to each wave and functions within the wave.

Wave planning has several benefits, among them; providing management with the ability to monitor and manage daily performance throughput, to respond to problems in a timely manner and generally utilising workers more effectively.

The following diagram demonstrates the daily flow of a typical wave planning operation:

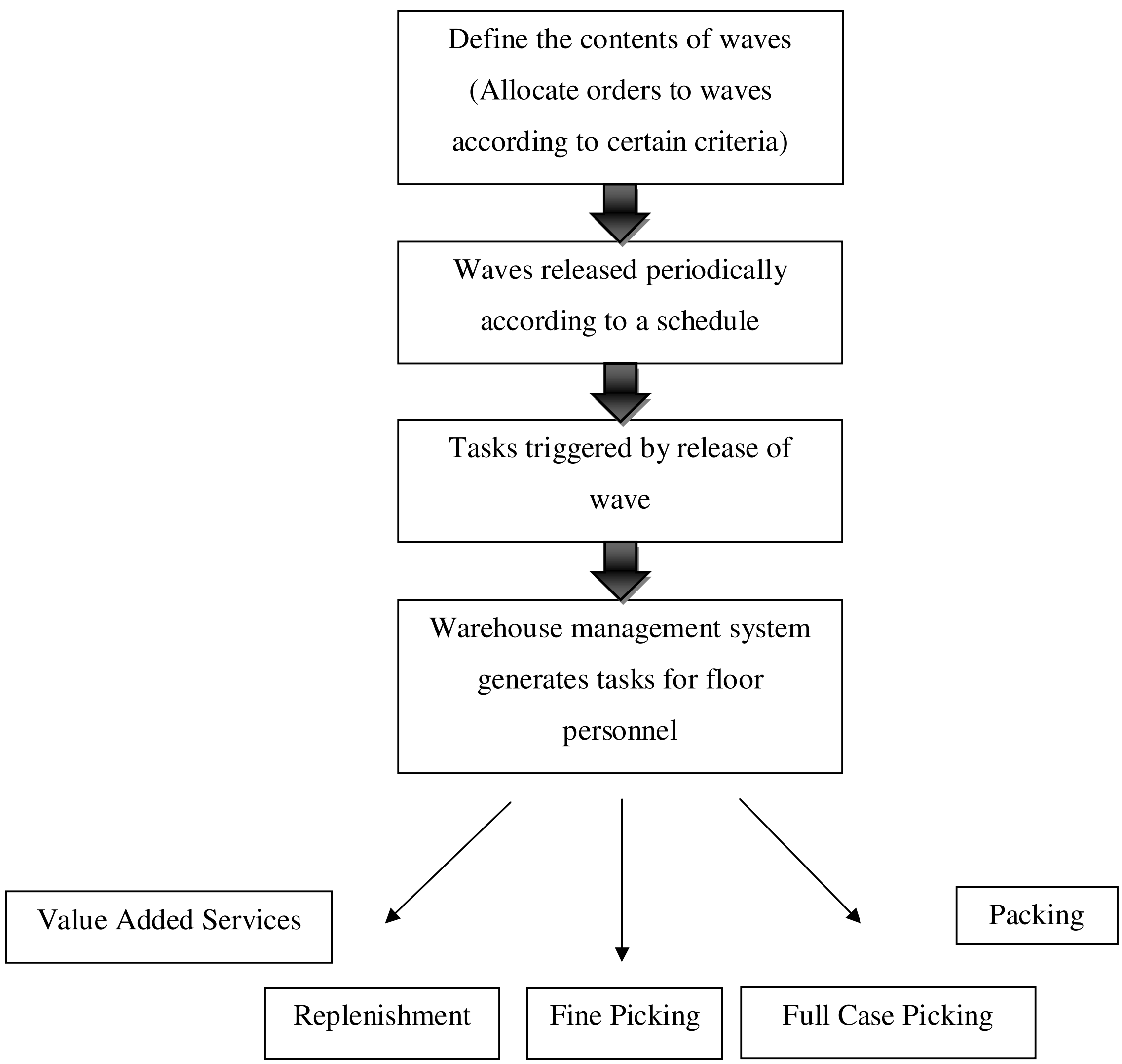


Figure 1.1: Typical wave planning operation

1.3 PROBLEM STATEMENT

At the Nike warehouse, Barloworld Logistics industrial engineers suspect that the outbound planning process and more specifically the daily wave planning process and the execution thereof can be improved in terms of average order processing time and general worker/resource productivity. Currently, waves are released simultaneously and orders are 'funnelled' down to be completed on a FIFO (first-in-first-out) basis with certain urgent tasks taking preference. This leads to a broken non-continuous flow as various delays occur throughout a typical day.

The current wave creation i.e. the sequence of orders and assignment to waves, the release schedule of waves, as well as worker resource allocation to functions within the waves all contribute to reduced efficiency. This non-optimal outbound planning process results in the daily workload not being completed on time which in turn leads to overtime and thus increased costs. An inability to effectively utilise employees, sufficiently monitor warehouse productivity and adapt to problem situations are further by-products of this situation.

2 PROJECT AIM

The goal of this project was to analyse the Nike warehouse operation and explore modern industrial engineering tools, techniques, best practices and algorithms that can be used to improve warehouse wave planning operations, taking into consideration operational and resource constraints, in order to test possible wave planning and execution alternatives and finally draw conclusions and make recommendations.

3 PROJECT SCOPE

The two basic aspects of wave planning are addressed by this project:

i. *The sequence of orders and assignment to waves;* the criteria which allocate orders to specific waves will be evaluated. The sequence and scheduling of waves as well as the functions within the waves will be addressed, while bearing operational and resource constraints in mind and considering other factors such as routing, loading, departure times and product requirements among others.

ii. *Assigning staff to each wave and functions within the wave;* the efficient utilisation of floor personnel is the other aspect of wave planning that will be addressed. The Nike warehouse has a certain percentage of specialised workers, multi-skilled workers and general less skilled labourers. Allocating these worker resources optimally to tasks triggered by the release of a wave (full case picking, fine picking, VAS, packing and replenishment) is the second major element of designing an efficient outbound process. Ideally, the available floor personnel must be assigned to activities such that each wave will be completed on time ensuring the completion of the daily workload (or at least minimising overtime) while providing management with the ability to monitor and manage performance throughout the day and to respond to problems that could occur in a timely fashion.

Both of the above mentioned aspects have been kept in scope since the two areas are so intertwined and affect each other to such a degree that they cannot be considered individually without taking the other into account. The tasks generated by the warehouse management system, ergonomics and productivity of these tasks, material handling methods and equipment, inventory storage layout or processes, and inbound processes are all out of scope.

4 LITERATURE REVIEW

4.1 INTRODUCTION

The purpose of this literature review is to investigate warehouse order picking policies, models and best practices that have been implemented in other warehouses in order to find appropriate model(s) that could be used as a more optimal alternative in a specific Nike warehouse. A breakdown of the aspects of warehouse order picking has been conducted to determine which aspects have the greatest impact on performance and should ideally be optimised first or at least concentrated on. An attempt is made at defining key operations of the Nike warehouse in order to make it comparable and relate it to other warehouses, thus narrowing down the search for similar warehouses where applicable order picking techniques and models have been applied. This will also allow the reader to become more familiarised with the warehouse configuration and gain a better understanding of the warehouse management system and the general work flow within the facility. Determining a suitable method to simulate the warehouse in question is a secondary objective which has been considered in this literature study. The practical applicability of each wave picking technique/model is imperative since unless the model can be applied in the case of the Nike warehouse it has very limited use to the eventual goal of this project.

4.2 WAREHOUSE ORDER PICKING

Warehouse order picking can be described as "withdrawing items from inventory to fulfil an order" (Business Dictionary, 2010), which sums up the outbound planning process at the Nike warehouse which this project aims to optimise. Thus research conducted for this literature review focussed on journals relating to order picking techniques and models. Order picking methods can fundamentally be broken down into the following steps: batching, routing/sequencing, and sorting (Gu, Goetschalckx, & McGinnis, 2007).

4.2.1 BATCHING

A set of orders, known as the pick-pool, are received and must be fulfilled daily. The objective of batching is then to partition this set of orders into batches, where each batch will be picked and packed during a time interval or "pick wave" (Gu, Goetschalckx, & McGinnis, 2007). The batches are planned such that when the first pick wave is completed the following batch is released and so forth, until the daily set of orders is completed. This approach has several benefits including high picking labour utilisation, and pick lists that are simultaneously calculated for all workers as the wave is released (Gallien & Weber, 2009) and easily communicated to the pickers via hand held scanning devices (in the Nike warehouse's case).

4.2.2 Routing

The sequence of picking SKUs on the pick list is referred to as the warehouses "routing" policy (Petersen & Aase, 2004). This policy determines the optimal route and sequence of locations for the picker to follow in order to complete a batch of orders in minimum time while minimising material handling cost (Gu, Goetschalckx, & McGinnis, 2007). Since solving this problem involves determining a sequence in which to visit different locations, where the orders to be picked are stored, it is often modelled as a travelling salesman problem (Daniels, Rummel, & Schantz, 1998).

The Nike warehouse sequencing and routing system is currently partially optimised. The system functions as follows:

- When a wave is released the picker instantly receives orders to be picked on a hand held scanning device. The worker then fetches an SKU from the designated location, scans the location to indicate an item has been picked and moves to the next location.
- Thus a picker can work on multiple orders simultaneously, provided they form part of the same wave.
- For example: If there are 10 orders that form part of the same wave, i.e. order 1,2...10, and the worker is signed in to pick, the following will occur:
    - The warehouse management system (WMS) will instruct the picker to begin with order 1, 2, 3 and 4 since a picker can handle 4 totes at one time.
    - As soon as the picker scans in his current location in the pick face, the WMS will optimise the route given the combined profile of the 4 orders that need to be picked. That is to say; the WMS determines an optimal route to follow in order to complete the 4 current orders.
- As soon as orders 1, 2, 3, and 4 are completed the picker will begin with orders 5, 6, 7, and 8.

Thus the system has a degree of local optimisation but there is no global optimisation present – orders are fulfilled on a first-come-first-serve basis as soon as the wave is released.

4.2.3 Sorting

When multiple items are picked together sorting is required, either during the picking process, known as "sort-while-pick," or after the picking process, known as "sort-after pick" (Gu, Goetschalckx, & McGinnis, 2007). The Nike warehouse does not require a complex sorting system as all picking is done manually and is simply sorted during picking activities since the pickers handle a maximum of four totes at a time.

Of the above mentioned processes *batching* is the nearest relation to wave planning and is the primary concern in the case of the Nike warehouse.

4.3 Defining the Warehouse

In order to find compatible models and techniques that can be fitted to the Nike warehouse, some warehouse aspects, such as layout, configuration and work flow, must first be defined. This section is concerned with identifying the major characteristics of the Nike warehouse that relate it to other similar warehouses. This creates a starting point from where order picking systems that have been successful in similar warehouses can investigated.

Warehousing systems, with respect to automation, can be divided into three categories (van den Berg & Zijm, 1999):

- Manual warehousing systems (picker-to-product)
- Automated warehousing systems (product-to-picker)
- Automatic warehousing systems (picker-less system)

The Nike warehouse falls into the manual warehousing system category as all order picking is done on a picker-to-product basis. The warehouse is divided into two sections. One section consists of conventional multiple parallel aisles with bulk items stored on pallet racks. The order picking performed here is known as "full case picking" and material handling is completed with the aid of forklifts. The second section, which is the primary focus of this project, consists of multiple aisles with multiple levels where order picking is conducted manually by workers using only totes as material handling equipment. Pickers receive order picking instructions, as described above under *routing,* and deposit fully picked totes onto gravity flow racks situated at the end of each level which takes the totes to be packed at the next station.

On a planning level, the current outbound planning process follows the following simplified procedure:

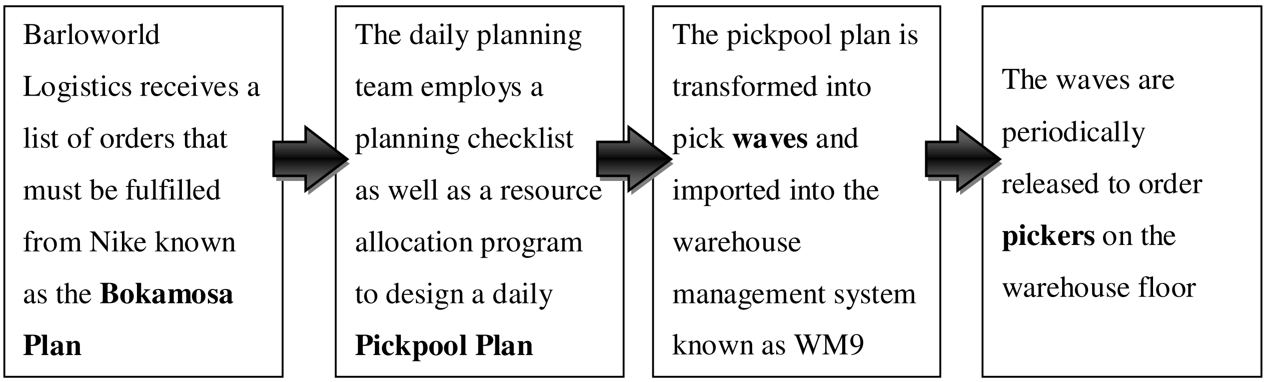


Figure 4.1: Nike warehouse daily outbound planning process

Additionally, the warehouse can be described as a *contract warehouse* as Barloworld Logistics operates the warehouse on behalf of Nike (van den Berg & Zijm, 1999).

4.4 ORDER PICKING METHODS

Common order picking policies used in a variety of warehouses has been investigated:

Strict Order Picking: In the most basic individual order picking, product is stored on static shelving or pallet racks. A manual picker-to-product system is employed with pickers picking items one at a time along aisles until depositing the completed order in designated location near the original starting point for smooth picking flow (Piasecki, 2001). Strict order picking is a common policy as it is easily implemented and order integrity is easily maintained (Petersen & Aase, 2004). However, such a configuration is only feasible in a small warehouse with a very limited amount of daily orders, which makes it completely infeasible for the complex Nike warehouse.

Batch Picking: The basic concept of batching is described above under *Warehouse Order Picking* and, as previously described, essentially consists of grouping multiple orders into smaller consolidated batches to be completed one at a time. However, there are many variations on batch picking including batching with sort-while-pick, batching with sort-after-pick, various combinations with zone picking such as sequential zone picking with batching and concurrent zone picking with batching per zone (Gu, Goetschalckx, & McGinnis, 2007). First-come-first-serve (FCFS) batching is a method which combines orders as they arrive until a maximum batch size has been reached (Petersen, 2000). Bin packing heuristics can also be applied and could result in fewer picking tours (Petersen & Aase, 2004). The fundamental principle behind bin-packing is packing a collection of items into bins of limited capacity while making efficient use of time and space (Smith, 2001). However, to apply this principle re-layout of the Nike facility is needed which is currently infeasible.

Zone Picking: This policy divides the warehouse into zones and assigns order pickers to specific zones (Petersen & Aase, 2004). Orders move from one zone to the next as picking from the previous zone is completed. It can be related to an assembly line version of order picking (Piasecki, 2001). Because pickers are dedicated to specific picking zones of a relatively small size, the picker achieves a high rate of item extraction in comparison to travelling time between locations, especially with an increased familiarity of SKUs within the zone (Gu, Goetschalckx, & McGinnis, 2007).

Wave Picking: Extensively discussed in Section *1.2 Problem Background* wave picking is a combination of zone and batch picking. Each picker is responsible for SKUs in their zone for multiple orders which have been batched into smaller "pick waves" (Petersen & Aase, 2004). This policy has been implemented since the establishment of the Nike warehouse and is well understood and ingrained into the mindset and approach of Barloworld Logistics/Nike employees. Wave planning is also the most suitable strategy for large complex warehouses with numerous orders, not to mention the configuration and material handling equipment is ideal for this type of order picking.

Order Picking Type:	**Total Orders:**	**Picks per Order:**
Strict Order Picking	Low	Moderate - High
Batch Picking	Low - High	Low
Zone Picking	Moderate - High	Low - Moderate

Wave Picking	Low - High	Moderate - High

Table 4.1: Comparison of order picking methods

(Piasecki, 2001)

4.5 WAVE PICKING ALTERNATIVES

It should be noted that making use of wave picking to fulfil orders is currently very much ingrained into the work culture and way of thinking of the Barloworld/Nike employees. Thus a radical change in direction away from wave planning to other alternatives, such as wave-less picking or drastically different batching techniques, would likely result in a large resistance to change mentality from the workforce. However, management requested that all options be looked into and so alternatives to wave planning have also been investigated.

Gallien & Weber (2009) propose a "wave-less release policy," also referred to as *wave-less picking* or *continuous flow picking* (Bradley, 2007). In contrast to traditional wave picking in which a second wave only commences when the first wave has been completed, wave-less picking involves a continuous flow of individual orders from the first to the second wave or queue, based on the urgency of the incoming customer order.

The second queue is limited to a maximum capacity. Any new order wishing to enter the system can only do so once another order has been fully completed and exited the queue. Unlike wave picking, in which entire pick waves are released periodically to pickers, pick lists are continually updated in real time. Zones are replaced by partitions known as picking loops and a dynamic partition in each picking loop shared by all pickers assigned to that zone. Thus, the appropriate labourer's pick list is continuously updated with all the items from orders in the picking queue between his last recorded position and that of the next worker in the same picking loop. A control method for re-assigning and balancing labour between zones is also necessary.

The primary benefit of this method is that no picker is ever starved for work at the end of a wave, which occasionally occurs during wave picking. However, wave-less picking has one major drawback; under certain circumstances the system can result in severe congestion known as *gridlock* (Johnson & Lofgren, 1994). Wave-less picking no longer releases batches of a fixed number of orders to be sorted at the end of a wave which normally ensures that accumulation space is never exceeded. Thus upstream congestion can build due to incomplete downstream orders, which could eventually result in pickers being unable to complete orders due to congestion from the very same partially completed orders blocking the downstream sorting mechanism/workers.

Nonetheless research has shown that a 35% increase in throughput rates (Honojosa, 1996) is possible for wave-based warehouses switched to a wave-less policy and is therefore definitely worth testing in a simulation model.

4.6 SIMULATION

According to Gu, Goetschalckx, & McGinnis one aspect of order picking which they refer to as "batching" can be described as: (The constraints and wording have been altered to fit into the Nike warehouse more closely)

Given:

(1) Warehouse layout and configuration
(2) Pick wave schedule
(3) Pick-pool (Orders to be picked during the shift)

Determine:

The sections of orders to be assigned to waves and pickers

Subject to:

Picking rates, resource capacity, shift times, picker capacity, material handling methods, order dates.

The above formulation describes the first aspect of wave planning which is currently suspected of being a non-optimal factor in the Nike warehouse's outbound planning process.

4.7 CONCLUSION

From the above literature it becomes obvious that wave planning is the most effective solution for order picking in the Nike warehouse. Therefore the focus needs to be shifted away from what types of order picking methods can be employed to what types of variations on wave planning can be tested or what aspects of wave planning can be altered. The only exception to this rule is the wave-less picking policy which has potential and will be tested by the project simulation along with wave picking variations.

As to the problem of determining a suitable method for warehouse simulation; the vast majority of algorithms developed for the optimisation of warehouse wave picking in the journal articles investigated are conducted using operations research.

5 DATA ANALYSIS

The overall purpose of the data analysis was to investigate the effect of pick wave content and sequencing on processing time in order to become aware of trends and tendencies of certain orders, within a wave, which can then be used as a logic to base a simulation upon.

In this case *processing time* is defined as the time taken to process an order from "release" to "shipped complete" status i.e. the time from when an order (within a wave) is released by the warehouse management system onto the warehouse floor, through picking, ticketing (if necessary) and packing to ready to be loaded and dispatched, known as "shipped complete" status.

Trends and tendencies are defined in terms of the effect that wave sequencing (the priority level given to a wave), wave order volume, order customer, order content (also known as BU – business unit divided into equipment, apparel and footwear) or any other primary order characteristic may have on the processing time of that order and other orders included within the same pick wave.

It should also be noted that customer orders are classified according to one of three categories:

- VAS IDP
- Non-VAS IDP
- Non-IDP

NB: A pick wave only contains one type of the above order types.

VAS or *Value Added Services* is an additional service that the Nike warehouse provides for some customers and includes *ticketing* and *pre-sorting* certain orders. Ticketing involves removing items from full case boxes, manually placing a price tag on each item and pre-sorting the items i.e. repacking the item into assorted boxes for the customer. The warehouse was not originally planned for this task, thus it has to be completed manually and takes a disproportionate amount of time (See Appendix for how VAS orders are currently completed) and must therefore be planned sufficiently ahead of time.

IDP or *Integrated Delivery Planning* orders have a specific date upon which they must be shipped and must therefore be ready to be dispatched on that specific date. Non-IDP orders, also known as PGI or *Planned Goods Issued*, have a shipping window within which they can be completed.

All VAS orders are also IDP orders and are therefore usually referred to only as VAS orders. Since the VAS task is a timely one and since IDP orders must be ready by a specific date, orders with these characteristics receive a high priority level. Priority levels are designated to waves by planners by adding a *P1, P2, P3…P8* to the name of the pick wave (See wave planning examples). A high priority order (and the wave within the order is placed) will be scheduled earlier and is an important factor to note when considering wave sequencing. Thus pick waves consisting of VAS and IDP orders will usually receive the highest priority, unless a Non-IDP order shipping window is about to end or past the due date. As a result VAS IDP waves are typically sequenced first (highest priority), Non-VAS IDP waves second and Non-IDP waves last.

A notable consideration is that while other waves consist of multiple orders, VAS orders are placed in their own individual waves as their volumes are usually large rounded figures merely requiring easy-to-pick full-cases and to ensure that they all arrive at the same time to the labourers conducting VAS operations (ticketing, pre-sorting and repacking), simplifying their task.

The main data analysed includes, but is not limited to:

- "Pickpool Plan"
- "Pickpool Summary"

The *Pickpool Plan* is the daily wave planning (sets of orders placed into waves planned to be picked for a specific day) done by the Barloworld daily planning team. The Pickpool Plan includes data on the order type (VAS IDP, Non-VAS IDP and Non-IDP), the *delivery docket number* (an external order key used to identify each individual order within a pick wave), the *business units* within each order (footwear, apparel, equipment or a combination) and their volumes, the wave name within which an order was placed, the wave priority and sequencing, the order status, the customer who requested the order, and the date upon which the order was made by the customer, amongst others.

The *Pickpool Summary* is a report requested and received from the warehouse management system used by Barloworld, known as WM9. This summary provides comprehensive historical information on every single individual order processed by the warehouse over a specific period of time. The most relevant and important data that this summary provides is the exact time and date which an order received “shipped complete” status i.e. the order has been picked packed and is ready to be dispatched.

This allows the processing time of individual orders within waves to be calculated and thus trends of specific order types, in terms of customer, volume, business units, priorities and so forth, to be analysed.

The order data analysed is dated form the 5th of January 2010 to the 2nd of August 2010, thus approximately 128 000 outgoing over the last 6 months were investigated.

The following diagram provides a clearer representation of how data analysis was conducted and how data was broken down into smaller more useful characteristics in order to detect order trends:

5.1 DATA ANALYSIS BREAKDOWN

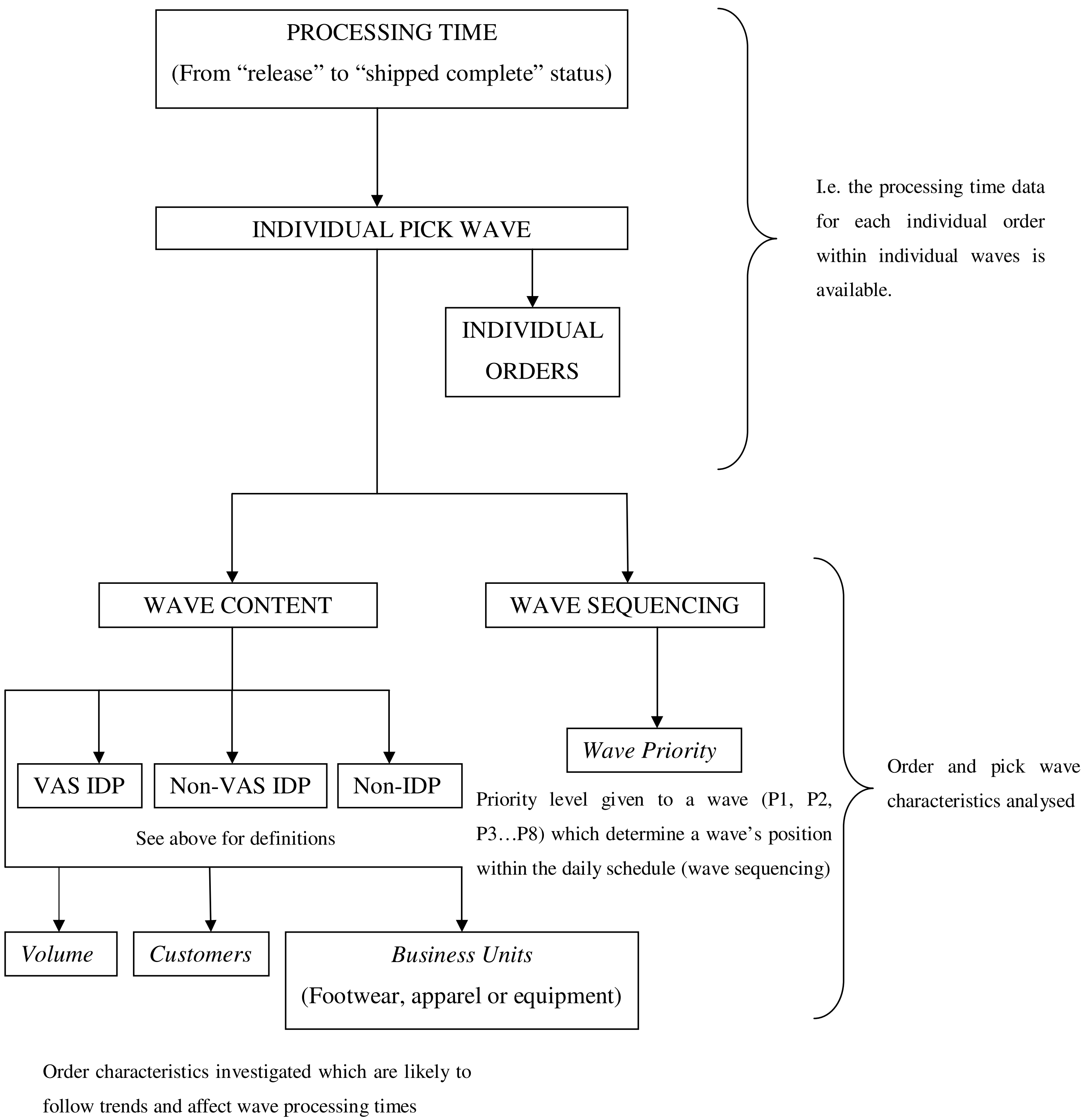


Figure 5.1: Data analysis breakdown

Other historical data samples analysed include:

- The daily list of orders to be fulfilled received by Barloworld Logistics from Nike, known as the "Bokamosa Plan"
- The pickpool plan constructed daily by the planning team
- The planning checklist used by the planning team to construct the daily pickpool plan
- The planning capacity model which aides the planning team in daily resource allocation activities
- The pickpool summary data used to convert orders into picking waves by the WM9 warehouse management system
- Timesheets detailing the amount of normal and overtime hours worked in each department by each worker per week
- "Daily Dashboards" indicating the weekly volumes picked, packed and shipped per department

Weekending 05.03.2010		Monday
Description	**Rate**	**N/T**
Packer Operator	R 22.60	7.50
Packer Operator	R 16.28	8.50
Packer Operator	R 16.28	
Packer Operator	R 16.28	8.50
Packer Operator	R 16.28	8.50
Packer Operator	R 16.28	8.50
Packer Operator	R 16.28	
Picker Operator	R 16.28	8.50
Picker Operator	R 16.28	8.50
Picker Operator	R 16.28	8.50
Picker Operator	R 16.28	8.50
Picker Operator	R 16.28	8.50
Picker Operator	R 16.28	6.00

Figure 5.2: Partial timesheet

		2010/05/03 Mon	
		1	
Picked	SKUGROUP	FC	FP
	APPAREL	12 656	6 551
	EQUIPEMNT	8 042	1 273
	FOOTWEAR	3 498	4 640
		24 196	**12 464**
Packed	SKUGROUP	FC	RP
	APPAREL	5 506	5 122
	EQUIPEMNT	4 886	1 150
	FOOTWEAR	6 570	4 434
		16 962	**10 706**
Shipped	SKUGROUP	QTY	
	APPAREL	9 693	
	FOOTWEAR	1 731	
	EQUIPEMNT	2 639	
	Summary	**14 063**	

Figure 5.3: Partial daily dashboard

Additional uses of data:

- Pickpool and WM9 data used to identify how waves are currently being constructed by the warehouse management system and processing output rates
- Data also used to establish base starting points to improve upon and find KPI's
- Determine labourer work rates by cross referencing the timesheet hours worked by employees with the amount of orders picked during that same period from the "Daily Dashboards"

See Appendices for further data examples. Portions of data could not be divulged due to their sensitive nature.

5.2 FLOW CHART OF DAILY WAVE PLANNING PROCEDURE

WAVE CONSTRUCTION AND SEQUENCING

In order to better understand the current wave construction and sequencing procedures followed by the Barloworld daily wave planners their planning tools and methods have been investigated. The following diagram illustrates a simplified version of the procedure followed by a daily planner working at the Nike warehouse. The initial steps of the planning method are completed by an automated program since they are generic and require no human input. However, the tasks of designing individual waves and then sequencing these waves fall to the best judgment of the of the wave planners and must be inputted manually. The diagram includes flow from the initial *'Bokamosa'* list of daily orders to be completed, which is received from Nike, through wave construction and sequencing up until completion of the pick waves, ready to be released to the warehouse floor by the warehouse management system WM9.

KEY:

The following legend includes all abbreviations used in the flow chart and a brief description of each term.

- **Delivery Docket (DD) Number** An external order key used to identify each individual order within a pick wave.
- **Integrated Delivery Planning (IDP)** An order type characterized by a specific dispatch date upon which the order must be ready to be shipped.
- **Planned Goods Issued (PGI)** Also known as **Non-IDP**. An order type characterised by a shipping window within which the order must be shipped.
- **Order Type** An order characteristic classified according to one of three categories: VAS IDP, Non-VAS IDP or Non-IDP.
- **Shipping Condition (SC**)** Order status indicated by one of the following:
  - **10 = Same Day** Delivery will leave the DC the same day it is created.
  - **20 = Rush** Delivery will leave the DC the day following its creation.
  - **30 = Regular** Delivery will leave the DC two days after its creation.
  - **35 = VAS** One extra processing day for VAS handling.
  - **35 = Export** One extra day for creating export documents.
  - **36 = Transit** Possible to take extra transit days into account for deliveries that require additional activities after shipment

    - **40 =Expedited** Delivery will leave the DC the day after its creation with an expedite carrier.

- **Value Added Services (VAS)** An additional service that the Nike warehouse provides for some customers and includes ticketing and pre-sorting certain orders.
- **Priority List** Preferred sequence of orders.
    1. RSG – Urgent Orders which must be dispatched the same day that are are dropped into the pickpool
    2. SC20 – See *Shipping Condition*
    3. Launch
    4. IDP
    5. Sportsmarketing
    6. Must ships
    7. Shippable
        - S1 FOS (Factory Outlet Store)
        - S2 Must Ships next day
        - S3 PP Aging
        - S4 Customer Targets
        - S5 Rest
    8. Rest of Pickpool
- **Business Units** Product type ordered defined by one of three codes: 10 = Apparel; 20 = Footwear; 30 = Equipment
- **Operations** Collection of supervisors working on the warehouse floor with labourers.
- **WM9** The warehouse management system employed at the Nike warehouse

The following is a simplified version of the document a Barloworld daily wave planner will have in front of them when planning wave construction and sequencing for the following day:

The first phase of the daily wave planning procedure (illustrated by the diagram below) is completed by an automated computer program since the steps are generic and require no human input (for example; tracing order keys to specific orders, flagging certain attributes of orders and detecting current order statuses):

Data Input into WM9 including but not limited to:

- DD – Delivery Document; Used as an Order Key
- IDP-flag
- Launch-flag
- Order Type
- Shipping Condition

Completed by Automated Program

The next phase of the wave planning procedure requires human input from members of the daily planning team. This includes adding necessary comments to orders, such as matching customers (retail companies) to orders and identifying orders which require value-added services (VAS) such as ticketing and pre-sorting of orders. Setting order priorities (which will later determine order sequencing within waves) is another step within this phase (see section *5.2 Wave Construction and Sequencing* for a more detailed explanation of the priorities listed in the figure below):

Make Overviews:

- Identify Company by Name
- Identify VAS Customers

Set Priorities:

1. RSG
2. SC20
3. Launch
4. IDP
5. Sportsmarketing
6. Must ships
7. Shippable
    a. S1 FOS

*Selection Priorities

Completed manually by daily wave planner

b. S2 Must Ships next day
c. S3 PP Aging
d. S4 Customer Targets
e. S5 Rest

8. Rest of pickpool

The third phase of the daily wave planning procedure involves a daily meeting between the Barloworld Logistics daily planning staff and the Nike planning team. Significant figures (such as VAS/Non-VAS IDP/Non-IDP order amounts currently in progress) are verified and orders with special requirements are discussed:

Daily Meetings

Check all individual order information

- Discuss pickpool and previous/next days with Operations (Warehouse floor supervisors)
- Discuss pickpool with Nike

In the next (and most significant, as far as this project is concerned) phase the actual daily pick waves are constructed using a template of rules as well as any additional factors that have been determined in the previous three phases:

Build Waves

- VAS orders: Separate into individual waves (Not too large)
- Non-Vas: According to selection priorities (*See previous page)
- Some criteria need separate waves (such as RSG, SC20)
- Start with wave number 1 to x and add orders according to selection criteria
- Stop when wave has reached wave size agreed upon with Operations
- Assign necessary comment and details to waves

Wave construction

The completed pick waves are imported into the warehouse management system (WM9) ready to be released according to schedule the following day:

Load Wave Planning Information into WM9 (Warehouse Management System)

↓

The morning before the daily wave plan (which was prepared the previous day) is released, the planning discuss the daily plan with the operations staff (supervisors to all warehouse floor staff including the order pickers) on the warehouse floor:

Discuss plan and sequence of waves with Operations staff

- Make wave overview
- 1st priority level: VAS
  - Find out how many units need to be processed for the day (VAS-overview)
  - Get waves for the same amount (earliest ship dates first)
- 2nd Priority Level
  - To ship today: First
  - To ship tomorrow: Second
    - Take selection criteria into account when multiple waves pop up
- To ship in 2 days: Third
    - Take selection criteria into account when multiple waves pop up
- If possible (enough capacity) add additional waves
  - Disregarding selection criteria, but not compromising ship dates

Sequencing of waves

Figure 5.4: Simplified daily wave planning procedure

6 RESULTS

The most significant results, from analysing the available data, were divided into three categories indicating the processing times of orders based on customer order type:

- VAS IDP
- Non-VAS IDP
- Non IDP

The results are discussed below, for a graphical interpretation see *Appendix B*, Figures 6.1 to 6.3.

All processing times were measured from the order status "Release" to the order status "Shipped Complete." The order enters the status "Release" the moment that is released by the warehouse management system, i.e. the order items are ready to be picked and are now waiting for an order picker to become available and complete the order as soon as possible. An order receives the status "Shipped Complete" as soon as the order is picked, packed and ready to be loaded and dispatched to the customer.

6.1 CUSTOMER ORDER TYPE PROCESSING – VAS IDP

According to the order data analysed only 8% of VAS orders are fully processed within the same day of being released to be picked. A low figure was expected, since the additional value added service rendered (ticketing and pre-sorting of specific orders) was not originally planned for and is currently a slow and laborious task. This is a worrying factor for the operation since this can and does result in a bottleneck within the order picking process. A short-term remedy for this situation is to give VAS IDP orders a high priority to ensure they are first in line to be processed, however in the long run a more effective and faster VAS method is required. Further; 37% of VAS IDP orders are processed within 1 day, 28% within 2 days, 17% within 3 days, 5% within 4 days, 3% within 5 days, and 2% within 6 or more days. In summary; 97% of VAS IDP orders are completed within 5 days and 89% within 3 days.

6.2 CUSTOMER ORDER TYPE PROCESSING – NON-VAS IDP

It was found that 57% of Non-VAS IDP orders are completed on the same day as reaching "Release" status. This high throughput rate can be attributed to the fact that IDP orders (orders which have a specific date upon which they must ship) receive a high priority rating and since they do not require any VAS, are consequently rapidly processed. Further; 28% of Non-VAS orders are processed within 1 day, 9% within 2 days, 3% within 3 days and the remaining 3% within 4 or more days. In summary; 97% of Non-Vas IDP orders were processed within 3 days and 85% within 1 day of being released to be picked.

6.3 Customer Order Type Processing – Non-IDP

Finally, it was found that 50% of Non-IDP orders are completed within the same day of being released to be processed. This figure is consistent with expectations since Non-IDP orders do not require VAS (vastly reducing their throughput times) but since they have a shipping window within which they can be completed, Non-IDP orders do not receive a high priority (unless the shipping window is past or coming to a close). Therefore the figure is less than the 57% of Non-VAS IDP orders completed on the same day of release. Further; 34% of Non-IDP orders are processed within 1 day, 9% within 2 days, 4% within 3 days, 1% within 4 days, 1% within 5 days and the remaining 1% within 6 or more days. In summary; 99% of Non-Vas IDP orders were processed within 5 days and 93% within 2 days of being released to be picked.

6.4 Processing Time Distribution

Distribution graphs were drawn from average processing time data for each of the above-mentioned three customer types. The distributions were used as simulation input to provide an approximate daily mix of orders. See *Appendix C*, Figures 6.4 to 6.6, for graphical illustrations.

7 DEVELOPMENT OF SUPPLEMENTARY TOOLS

7.1 SIMULATION

A simulation was required in order to test the effects of order characteristics on each other, within the context of wave planning. The simulation was constructed using historical data to find an average daily mix of orders (See Section *6 Data Analysis* for a complete description of the data collected as well as how the information was employed in regard to constructing a simulation). The input data consists of a sequence of orders and their assignment to waves. The purpose of this will be to find comparable output data (time taken to complete the daily workload) and decide upon a preferred wave planning solution algorithm to test in practice.

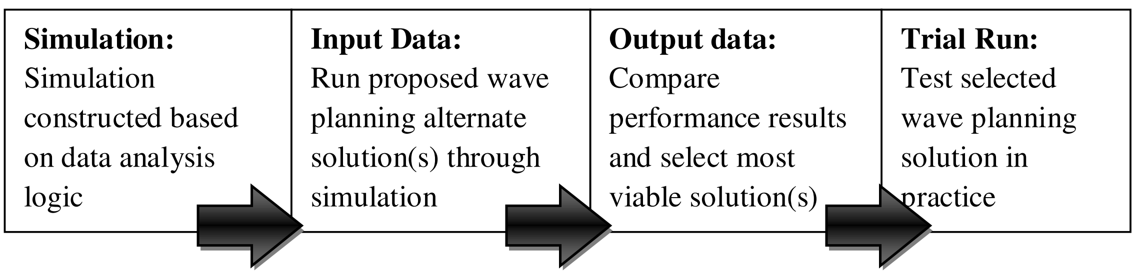


Figure 7.1: Application of simulation

Arena simulation software was used to conduct a simulation:

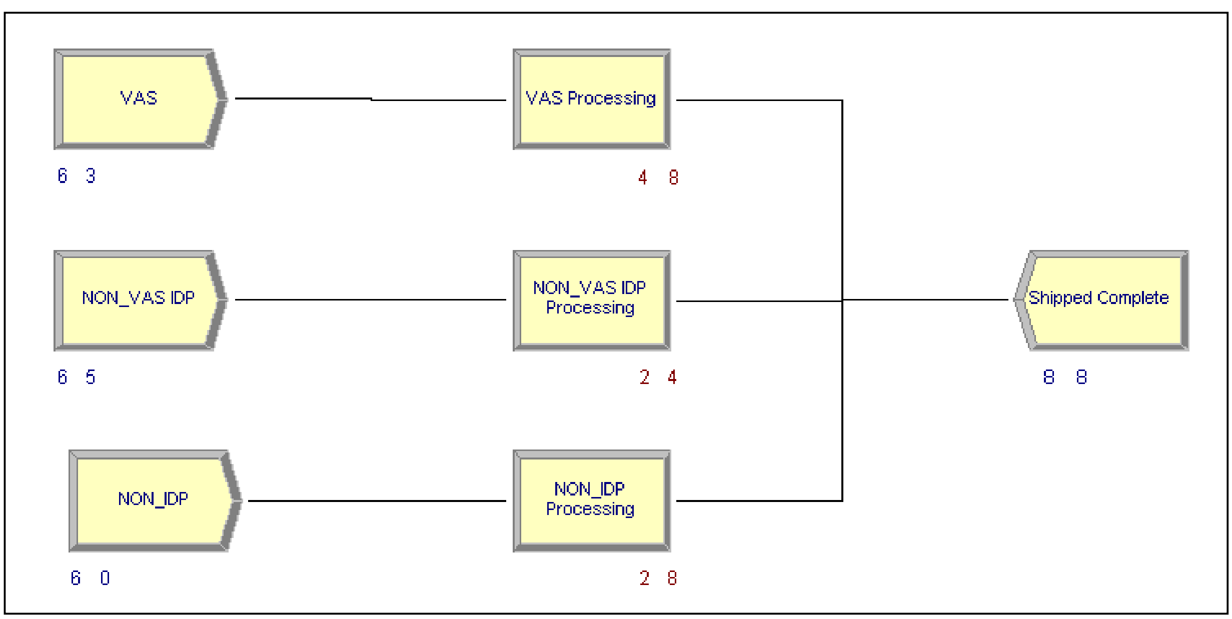


Figure 7.2: Arena simulation in progress

To view a summary of the simulation output, see *Appendix D*.

While this model was useful in detecting possible areas for improving the current wave planning to some extent, certain flaws in the raw data may have led to inconsistent results. For example:

- There was evidence of several ‘holes’ in the data where order numbers were missing and could not be traced to a daily pick pool plan. Where the original data contained approximately 120 000 orders, the useable order data was estimated to be around 40 000.
- Orders were not consistently flagged as VAS/Non-VAS IDP/Non-IDP and often assumptions had to be made on certain order attributes.
- A number of the figures and reports were not consistent with previous reports constructed which apparently used the same data.
- A portion of data was collected during the Soccer World Cup period earlier this year, where an abnormal amount of stock and orders were being moved through the warehouse.
- A section of daily pick pool planning sheets were in a different format compared to the majority of the planning reports, with order attributes being listed under different labels.
- The general impression was that the data employed was not entirely reliable and that the useable samples used were too few and too inconsistent.

Nevertheless, despite the above mentioned difficulties certain observations could be made and conclusions drawn from the analysis of the warehouse.

8 SOLUTION

Two major planning elements of the outbound processes within the warehouse which are likely candidates for improvement have been identified:

- The construction of waves by the planning team with the aid of a *planner's checklist* and a *capacity planning model* which aides resource allocation of workers
- The priority levels and sequencing of waves after they have been constructed

While it was found that there is opportunity for improvement on both of these sides of the outbound planning process, the design of pick waves currently has the greatest potential for improvement, especially considering that the warehouse has recently updated its system of prioritising orders since the start of this project.

This view has been reinforced by the literature review as it became obvious that, due to the high throughput rate and complexity of the Nike warehouse, strict order picking, normal batching or zoning methods are not suitable or feasible as alternative order picking solutions which leaves wave picking – the method currently in use. The warehouse configuration, material handling equipment and the general mindset of Barloworld/Nike employees is ideally suited for this use of wave planning as the warehouse's order picking policy.

Therefore focus has been shifted away from alternative order picking methods to what variations on wave planning can be employed to increase throughput and productivity. The following alterations to the current wave planning method can be tested in practice and compared to the present throughput rates:

- Decreasing wave sizes to the minimum practical amount. Theoretically, this should increase productivity since any idle or slow time pickers may experience at the end of waves is reduced, thus promoting continuous flow.
- Waves should be simplified as far as possible by limiting variation on customer and order types per wave
- Large orders of similar SKU's should be grouped together allowing bulk full cases to be picked and reducing laborious fine picking
- Alternating methods of how workers are assigned to waves
- Testing of the *waveless release policy*. This is the only exception to the rule of keeping with wave planning since waveless picking revolves around many of the

same principles of wave picking. The waveless picking method is described in greater detail in the literature review.

As mentioned in the literature review, the current routing policy employed in the Nike warehouse is only partially optimised (only local optimisation is present not global, see section *4.2.2 Routing*). While this is something to keep in mind, routing is on the fringes of the scope and therefore does not deserve attention at the moment.

GLOSSARY

Business Units Product type ordered defined by one of three codes: 10 = Apparel; 20 = Footwear; 30 = Equipment

Bokamosa Plan The plan received daily by Barloworld from Nike detailing the orders to be picked and dispatched to customers in the short-term future.

Delivery Docket (DD) Number An external order key used to identify each individual order within a pick wave.

Fine Picking One-at-a-time picking of customer orders.

Full case Cases with a fixed volume of a certain product. E.g. Nine pairs of Nike Pegasus shoes size 7.

Integrated Delivery Planning (IDP) An order type characterized by a specific dispatch date upon which the order must be ready to be shipped.

Operations Collection of supervisors working on the warehouse floor with labourers.

Order Type An order characteristic classified according to one of three categories: VAS IDP, Non-VAS IDP or Non-IDP.

Pick Wave Segment of orders to be released to be processed according to a scheduled sequence.

Pickpool A collection of orders to be picked, usually grouped together per day.

Planned Goods Issued (PGI) An order type characterised by a shipping window within which the order must be dispatched. Also known as **Non-IDP**.

Pre-sorting The manual process of removing items from full cases and re-packing them according to a customer order. Usually done in conjunction with *Ticketing*.

Priority List Preferred sequence of orders.

9. RSG – Urgent Orders which must be dispatched the same day that are are dropped into the pickpool
10. SC20 – See *Shipping Condition*
11. Launch
12. IDP
13. Sportsmarketing
14. Must ships
15. Shippable
    - S1 FOS (Factory Outlet Store)
    - S2 Must Ships next day

- S3 PP Aging
- S4 Customer Targets
- S5 Rest

16. Rest of Pickpool

Shipping Condition (SC)** Order status indicated by one of the following:

- **10 = Same Day** Delivery will leave the DC the same day it is created.
- **20 = Rush** Delivery will leave the DC the day following its creation.
- **30 = Regular** Delivery will leave the DC two days after its creation.
- **35 = VAS** One extra processing day for VAS handling.
- **35 = Export** One extra day for creating export documents.
- **36 = Transit** Possible to take extra transit days into account for deliveries that require additional activities after shipment
- **40 =Expedited** Delivery will leave the DC the day after its creation with an expedite carrier.

Ticketing The manual placing of customer price tags onto items. See *VAS*.

Value Added Services (VAS) An additional service that the Nike warehouse provides for some customers and includes ticketing and pre-sorting certain orders.

Wave Picking An order picking method involving orders being placed into segments and released to be picked periodically in a particular sequence.

Wave Planning See *Wave Picking*.

Wave Priority See *Wave Sequencing*.

Wave Sequencing The order

WM9 The warehouse management system employed at the Nike warehouse

WM9 Statuses The various statuses which the warehouse management system confers to each order which has been released to the warehouse floor to be processed.

References

Bradley, P. (2007). *Smoothing the waves.* Massachusetts: DC Velocity.

Daniels, R. L., Rummel, J. L., & Schantz, R. (1998). A model for warehouse order picking. *European Journal of Operational Research 105* , 1-17.

Gademann, N., & Velde, S. (2005). Order batching to minimize total travel time in a parallel-aisle warehouse. *IIE Transactions Volume 37 Issue 1* , 63 — 75.

Gallien, J., & Weber, T. (2009). To Wave Or Not To Wave? Order Release Policies for Warehouses with an Automated Sorter. *Supply Chain Digest 8* , 1-37.

Gu, J., Goetschalckx, M., & McGinnis, L. F. (2007). Research on warehouse operation: A comprehensive review. *European Journal of Operational Research 177* , 1–21.

Honojosa, A. (1996). Designing distribution centers: Shifting to an automated system. *IIE Solutions 5* , 32—37.

Hsieh, L.-f., & Tsai, L. (2006). The optimum design of a warehouse system on order picking efficiency. *International Journal of Advanced Manufacturing Technology 28* , 626–637.

Johnson, E., & Lofgren, T. (1994). Model decomposition speeds distribution center design. *Interfaces 24(5)* , 95—106.

Petersen. (2000). An evaluation of order picking policies for mailorder companies. *Production and Operations Management 9* , 319–335.

Petersen, C. G., & Aase, G. (2004). A comparison of picking, storage, and routing policies in manual order picking. *International Journal of Production Economics 92* , 11–19.

Piasecki, D. (2001). *Order Picking: Methods and Equipment for Piece Pick, Case Pick, and Pallet Pick Operations.* Retrieved May 11, 2010, from InventoryOps: http://www.inventoryops.com

SAPA. (2010, March 1). *Business*. Retrieved March 23, 2010, from SouthAfrica.info: http://www.southafrica.info/news/business/254516.htm

Smith, H. (2001). *Bin Packing Explained.* Retrieved May 11, 2010, from Bin Packing: http://users.cs.cf.ac.uk/C.L.Mumford/heidi/Background.html

Technology, S. (2005). *What is a Warehouse Management System (WMS)?* Retrieved March 23, 2010, from Senic Technology: http://www.scenictechnology.com

van den Berg, J. P. (1991). A literature survey on planning and control of warehousing systems. *IIE Transactions 31* , 751-762.

van den Berg, J. P., & Zijm, W. H. (1999). Models for warehouse management: ClassiÞcation and examples. *International Journal of Production Economics 59* , 519-528.

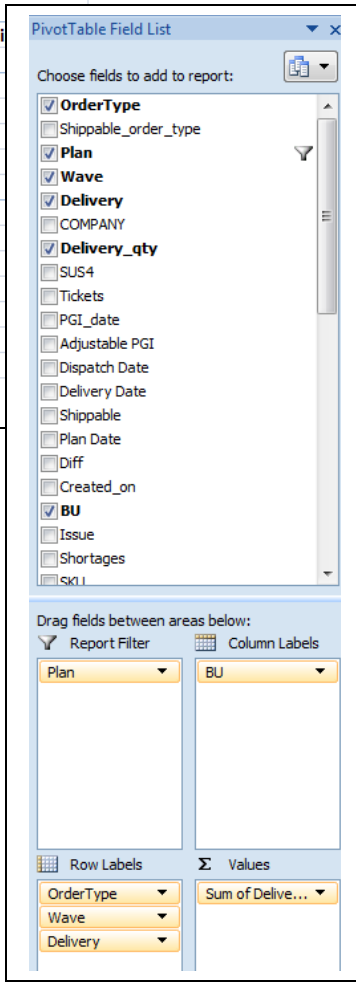
Wikipedia. (n.d.). *Wave Picking*. Retrieved March 23, 2010, from Wikipedia: http://en.wikipedia.org/wiki/Wave_Picking

APPENDIX

APPENDIX A

DAILY WAVE PLAN "PICKPOOL PLAN" 2010/01/05 – 2010/08/02

Plan	2010/07/26					
Sum of Delivery_qty			**BU**			
OrderType	**Wave**	**Delivery**	**10**	**20**	**30**	**Grand Total**
0 VAS	**20100726_1.1_VAS_STUDIO88(P2)**	446608658	300			300
	20100726_1.2_VAS_SPORTSDIV(P2)	446964710	451			451
	20100727_1.3_VAS_EDCON(P2)	446813976	400			400
	20100727_1.4_VAS_STUDIO88(P2)	446609343		1200		1200
	20100727_1.5_VAS_STUDIO88(P2)	446612412		1500		1500
	20100728_1.6_VAS_EDCON_PRE-SORT(P2)	446717382		1634		1634
	20100728_1.7_VAS_MARKHAMS(P2)	445654628		3200		3200
00 URGENT - PGI Date Pa:	**20100726_2.1_URGENT_PGI_DATE(P3)**	446976476			4	4
		447036232			5	5
		447046340			3	3
		447047829			3	3
		447052484			4	4
		447056742			5	5
		447056964			3	3
		447059357			4	4
		447063719			4	4
		447064811			3	3
00 Urgent - shi	**TE(P4)**					
02 SC20						
03 Launch						



Delivery	Total	DATE ADDED	SHIPPED COMPLETE	PROCESSING TIME
446608658	300	2010/07/19	2010/07/26	6
446964710	451	2010/07/22	2010/07/26	3
446813976	400	2010/07/20	2010/07/26	5
446609343	1200	2010/07/20	2010/07/26	5
446612412	1500	2010/07/20	2010/07/27	6
446717382	1634	2010/07/19	2010/07/29	9
445654628	3200	2010/07/15	2010/07/26	8
446976476	4	2010/07/23	2010/07/26	2
447036232	5	2010/07/23	2010/07/26	2
447046340	3	2010/07/23	2010/07/26	2
447047829	3	2010/07/23	2010/07/26	2
447052484	4	2010/07/23	2010/07/26	2
447056742	5	2010/07/23	2010/07/26	2
447056964	3	2010/07/23	2010/07/26	2
447059357	4	2010/07/23	2010/07/26	2
447063719	4	2010/07/23	2010/07/26	2
447064811	3	2010/07/23	2010/07/26	2
447065016	4	2010/07/23	2010/07/26	2
446952623	6	2010/07/23	2010/07/26	2
446963618	5	2010/07/23	2010/07/26	2
446960771	5	2010/07/23	2010/07/26	2
446996653	15	2010/07/23	2010/07/26	2
447032283	2	2010/07/23	2010/07/26	2
447044436	2	2010/07/23	2010/07/26	2
447044437	2	2010/07/23	2010/07/26	2
446889694	25	2010/07/23	2010/07/26	2
447042046	3	2010/07/23	2010/07/26	2
447046083	3	2010/07/23	2010/07/26	2
447046335	4	2010/07/23	2010/07/26	2
447050659	3	2010/07/23	2010/07/26	2
447050660	4	2010/07/23	2010/07/26	2
447052533	103	2010/07/23	2010/07/26	2
447052534	11	2010/07/23	2010/07/26	2
447052539	6	2010/07/23	2010/07/26	2
447052540	11	2010/07/23	2010/07/26	2
447052544	4	2010/07/23	2010/07/26	2

Figure 5.2: Partial "Pickpool Plan" examples

REPORT DATA RECEIVED FROM THE WAREHOUSE MANAGEMENT SYSTEM

"PICKPOOL SUMMARY"

2010/01/05 – 2010/08/02

EXTORDERKEY	COMPANY	PURC_ORDER	MATERIAL	DROUTE	QTY	QTYOPEN	QTYSHIP	QTYADJ	QTYPREALL	QTYALL	QTYPIC	NO_LINES	DATEADDED
442883271	FOS - CAPE TOWN	835574400	324909-001	3	4	0	4	0	0	0	0	1	2010/03/19 11:03
441787629	SMW RONDEBOSCH 701	834838036	325047-141	2	9	0	9	0	0	0	0	6	2010/02/15 11:17
441825601	SMW TOKAI 708	834838038	325047-141	2	7	0	7	0	0	0	0	4	2010/02/15 11:17
441189805	TEKKIE TOWN - STONERIDGE CENTRE	834371195	325047-141	2	6	0	6	0	0	0	0	6	2010/02/02 10:38
441028215	FOS - LINKSFIELD	834179439	287650-655	2	42	0	41	-1	0	0	0	4	2010/01/20 11:49
442867668	SNEAKERS EDITION BEDFORDVIEW	835160518	BA2133-067	2	4	0	0	0	0	0	0	1	2010/03/18 11:48
442148078	CSC - CHARLES NDLOVU	835059169	BA2133-067	2	1	0	1	0	0	0	0	1	2010/02/24 11:33
442037289	NIKE MOBILE STORE	834939483	287548-614	2	30	0	30	0	0	0	0	1	2010/03/02 11:21
441193819	TEKKIE TOWN KIMBERLEY	834354957	325047-001	2	6	0	6	0	0	0	0	5	2010/02/02 10:39
440796851	FOS - PRETORIA	833586504	287630-105	2	2	0	0	-2	0	0	0	1	2010/01/14 11:18
442235948	ECONOMIC SHOES	829673869	325047-001	3	12	0	12	0	0	0	0	6	2010/03/02 11:19
440856678	FRAME SAMMY MARKS												01/14 11:17
442699808	NIKE ONLY WEST STREET												03/12 10:47
442699821	NIKE ONLY-GATEWAY												03/12 10:48
441875937	FOS - PRETORIA												02/16 11:17
441774955	FOS - CAPE TOWN												02/12 10:46

DDED	DELIVERYDATE2	STATUS	SKUGROUP	CUST_PO	LASTEDITTIME
3/19 11:03	2010/03/19 00:00	Shipped Complete	20	56617M RUNNING	2010/03/24 13:13
2/15 11:17	2010/02/15 00:00	Shipped Complete	20	10256361	2010/02/16 10:39
2/15 11:17	2010/02/15 00:00	Shipped Complete	20	10256361	2010/02/16 10:18
2/02 10:38	2010/01/27 00:00	Shipped Complete	20	NIKEFEB2010.21	2010/02/03 14:08
1/20 11:49	2010/02/04 00:00	Shipped Complete	10	07582M FOOTBALL ACTIVE	2010/02/01 06:10
3/18 11:48	2010/03/03 00:00	Cancelled Internally	30	NDUMISO - EASTGATE	2010/03/24 11:46
2/24 11:33	2010/02/24 00:00	Shipped Complete	30	CHARLES NDLOVU	2010/02/25 13:16
3/02 11:21	2010/03/04 00:00	Shipped Complete	10	29604M FOOTBALL TRAIN	2010/03/10 10:02
2/02 10:39	2010/01/27 00:00	Shipped Complete	20	NIKEFEB2010.20	2010/02/03 13:35
1/14 11:18	2009/12/30 00:00	Shipped Complete	10	95167M TENNIS APP	2010/01/20 13:37
3/02 11:19	2010/03/10 00:00	Shipped Complete	20	ECO3	2010/03/04 07:58
1/14 11:17	2010/01/19 00:00	Shipped Complete	20	Mar-48	2010/01/18 06:05
3/12 10:47	2010/03/17 00:00	Shipped Complete	20	BOYS PRE SCHOOL BOY PRSCH MILE	2010/03/19 15:51
3/12 10:48	2010/03/17 00:00	Shipped Complete	20	BOYS PRE SCHOOL BOY PRSCH MILE	2010/03/24 11:05

Figure 5.3: Partial example of "Pickpool Summary" report

APPENDIX B

6 RESULTS

The following results indicate the processing times of orders based on customer order type divided into three categories:

6.1 CUSTOMER ORDER TYPE PROCESSING – VAS IDP

"Release" to "Shipped Complete" Status

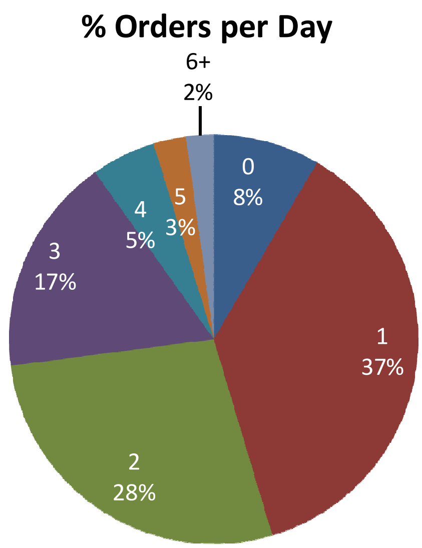


Figure 6.1: Days required for percentage of VAS IDP orders to be picked, ticketed, pre-sorted and packed to "Shipped Complete" status

- 8% of orders processed on the same day
- 37% of orders processed within 1 day
- 28% of orders processed within 2 days
- 17% of orders processed within 3 days
- 5% of orders processed within 4 days
- 3% of orders processed within 5 days
- 2% of orders processed within 6+ days
- 97% of VAS IDP orders processed within 5 days
- 89% of VAS IDP orders processed within 3 days

6.2 Customer Order Type Processing – Non-VAS IDP

"Release" to "Shipped Complete" Status

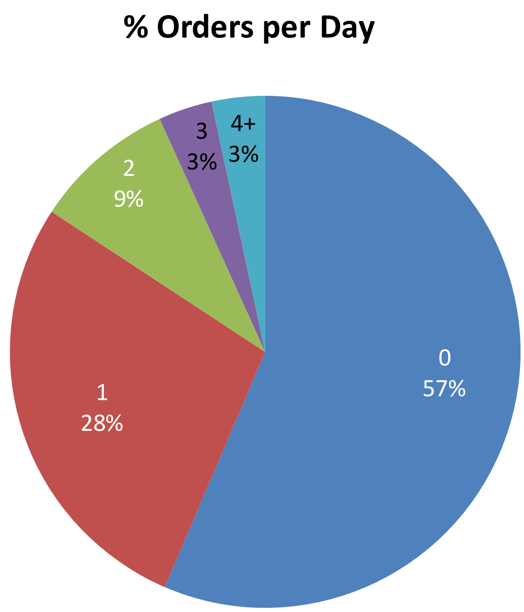


Figure 6.2: Days required for percentage of Non-VAS IDP orders to be picked, sorted, and packed to "Shipped Complete" status

- 57% of orders processed on the same day
- 28% of orders processed within 1 day
- 9% of orders processed within 2 days
- 3% of orders processed within 3 days
- 3% of orders processed within 4 or more days
- 97% of orders processed within 3 days
- 85% of orders processed within 1 days

6.3 CUSTOMER ORDER TYPE PROCESSING – NON-IDP

"Release" to "Shipped Complete" Status

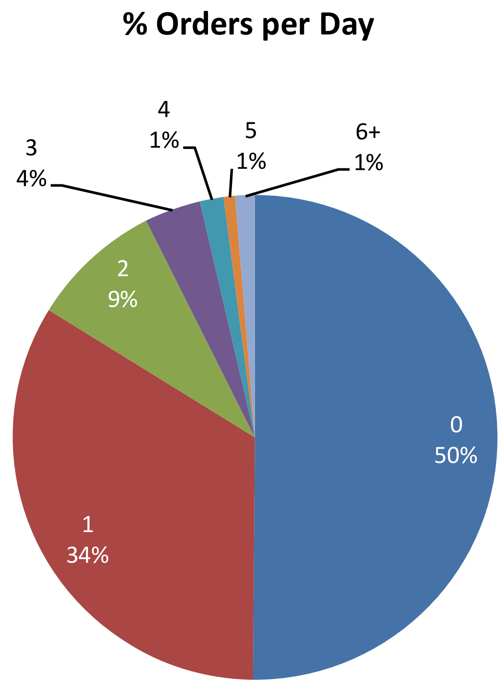


Figure 6.3: Days required for percentage of Non-IDP orders to be picked, sorted, and packed to "Shipped Complete" status

- 50% of orders processed on the same day
- 34% of orders processed within 1 day
- 9% of orders processed within 2 days
- 4% of orders processed within 3 days
- 1% of orders processed within 4 days
- 1% of orders processed within 5 days
- 1% of orders processed within 6 or more days
- 99% of orders processed within 5 days
- 93% of orders processed within 2 days

APPENDIX C

6.4 PROCESSING TIME DISTRIBUTION

The following distribution graphs were drawn from average processing time data for each of the above-mentioned three customer types. The distributions were used as simulation input to provide an approximate daily mix of orders.

VAS IDP

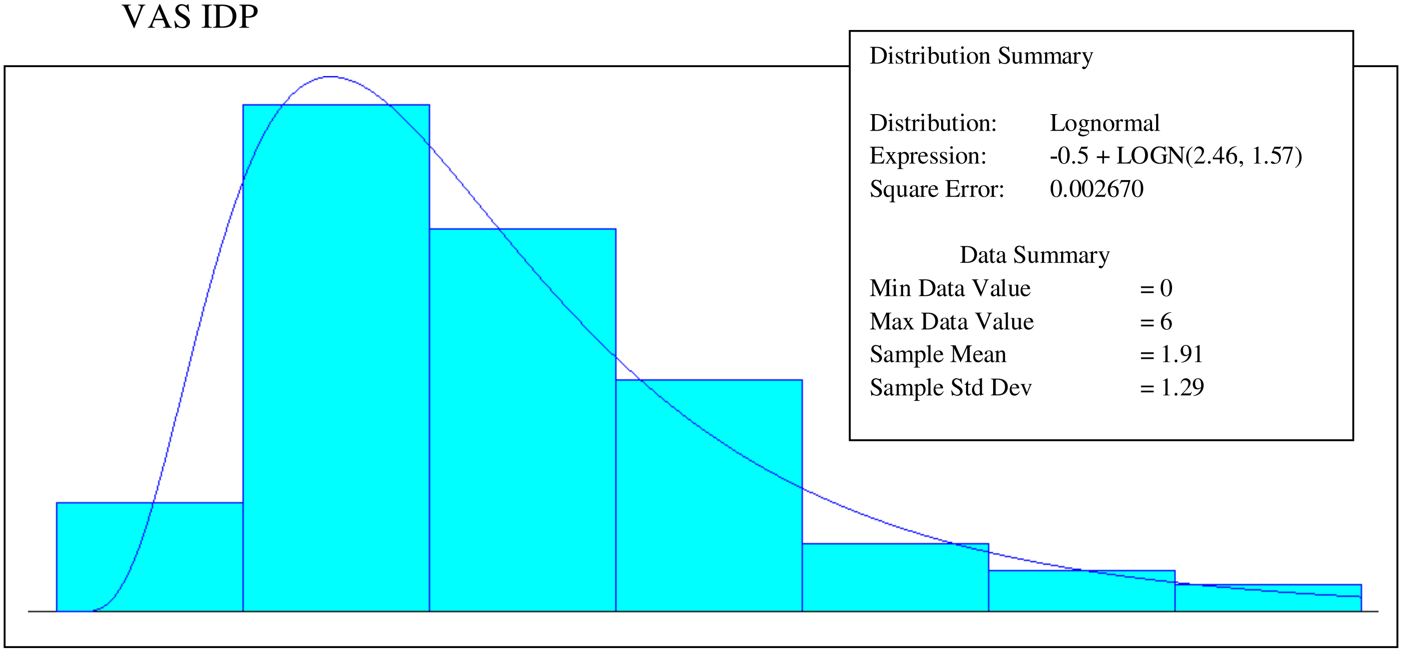
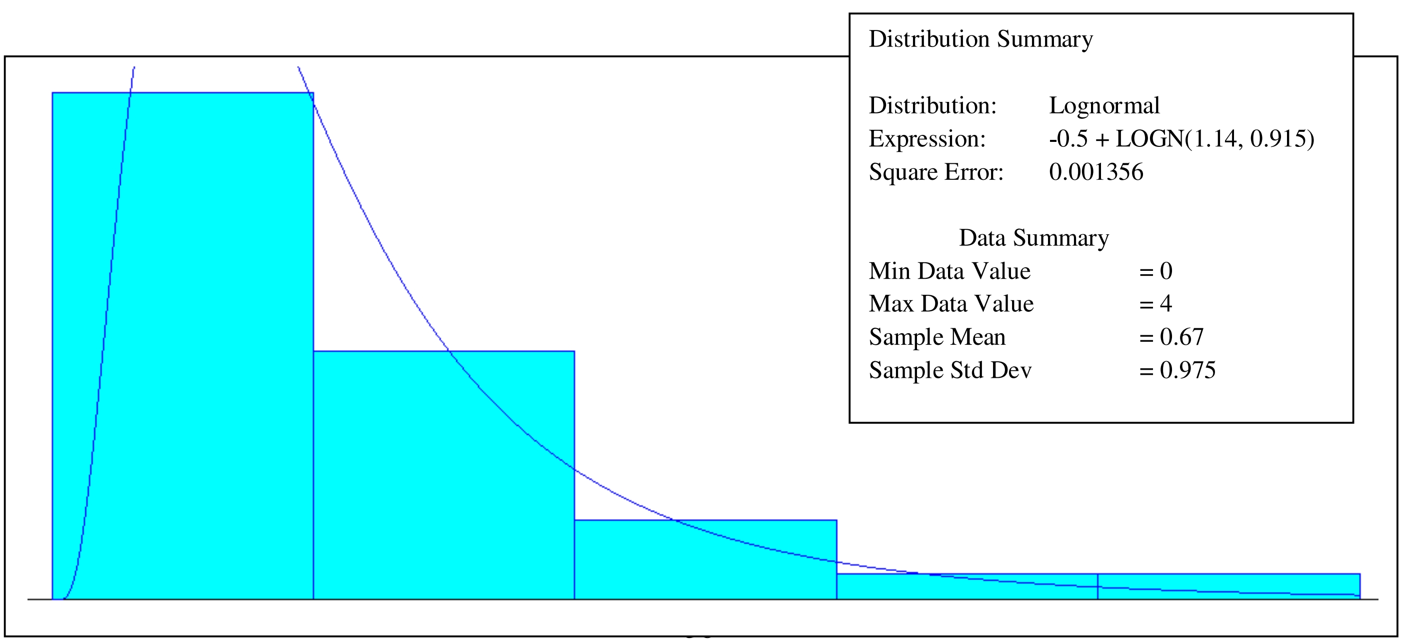


Figure 6.4: VAS IDP Processing Time Distribution

NON-VAS IDP



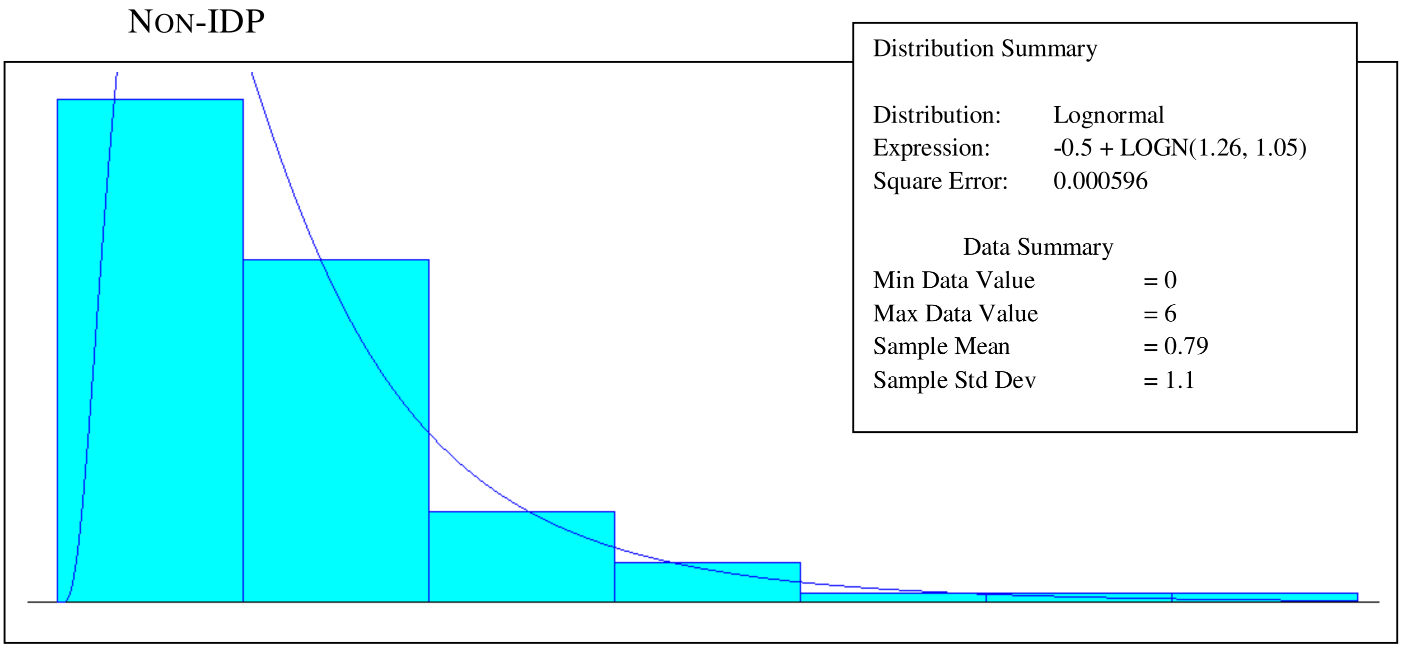


Figure 6.6: Non-IDP Processing Time Distribution

APPENDIX D

SIMULATION OUTPUT SUMMARY

The following output data was collected from the Arena simulation model. While the data may be somewhat unreliable, as detailed in the report (See *Section 7 Development of Supplementary Tools*) the results did provide some insight.

The output times are measured in hours, with 8 hours constituting a full work day. *VA Time* indicates value added time i.e. the time spent processing (picking, sorting and packing) an order. Average *WIP* (work in progress) figures are in terms of percentages. Outputs are a combined average of 100 replications.

All three customer order types at equal levels:

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
NON_IDP Order	8.3115	(Insufficient)	0.00	64.5103
NON_VAS IDP Order	6.0736	(Insufficient)	0.00	33.4020
VAS Order	15.1494	(Insufficient)	0.00	80.7194

WIP	Average	Half Width	Minimum Value	Maximum Value
NON_IDP Order	10.0138	(Insufficient)	0.00	42.0000
NON_VAS IDP Order	7.3175	(Insufficient)	0.00	31.0000
VAS Order	18.2523	(Insufficient)	0.00	63.0000

VAS IDP orders increased by 30% and Non-VAS IDP/Non-IDP orders decreased proportionately:

VA Time	Average	Half Width	Minimum Value	Maximum Value
NON_IDP Order	8.8961	(Insufficient)	0.00	64.5103
NON_VAS IDP Order	5.8556	(Insufficient)	0.00	33.4020
VAS Order	15.4196	(Insufficient)	0.00	80.7194

WIP	Average	Half Width	Minimum Value	Maximum Value
NON_IDP Order	9.1105	(Insufficient)	0.00	41.0000
NON_VAS IDP Order	5.9967	(Insufficient)	0.00	27.0000
VAS Order	24.1511	(Insufficient)	0.00	63.0000

Non-VAS IDP orders increased by 30% and VAS IDP/Non-IDP orders decreased proportionately:

VA Time	Average	Half Width	Minimum Value	Maximum Value
NON_IDP Order	8.8961	(Insufficient)	0.00	64.5103
NON_VAS IDP Order	5.7507	(Insufficient)	0.00	33.4020
VAS Order	15.0825	(Insufficient)	0.00	80.7194

WIP	Average	Half Width	Minimum Value	Maximum Value
NON_IDP Order	9.1105	(Insufficient)	0.00	41.0000
NON_VAS IDP Order	9.0071	(Insufficient)	0.00	36.0000
VAS Order	15.4459	(Insufficient)	0.00	61.0000

Non-IDP orders increased by 30% and VAS IDP/Non-VAS IDP orders decreased proportionately:

VA Time	Average	Half Width	Minimum Value	Maximum Value
NON_IDP Order	8.0604	(Insufficient)	0.00	64.5103
NON_VAS IDP Order	5.8556	(Insufficient)	0.00	33.4020
VAS Order	15.0825	(Insufficient)	0.00	80.7194

WIP	Average	Half Width	Minimum Value	Maximum Value
NON_IDP Order	12.6247	(Insufficient)	0.00	44.0000
NON_VAS IDP Order	5.9967	(Insufficient)	0.00	27.0000
VAS Order	15.4459	(Insufficient)	0.00	61.0000