

# Re-Design of a Current State Push Based Towards a Future State Pull Based Logistic System for Royal FloraHolland

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# Re-Design of a Current State Push Based Towards a Future State Pull Based Logistic System for Royal FloraHolland

by

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# Summary

The research is carried out for the cooperation Royal FloraHolland Aalsmeer and focuses on the logistics of the flower auction order handling process. Each day around 30.000 transactions are created at this auction, and all these transactions will be processed alongside the auction. Currently the required on-time delivery performance is below the norm which leads to unsatisfied clients. The demand for the process has changed over the years as the products are split in smaller transactions resulting in more work for the order handling process. Also an outdated information system is used to coordinate the process in which a paper ticket is printed for each transaction. This ticket contains all information required for processing the transaction. Printing the tickets for around 30.000 transactions each day is costly and therefore it is desired to discard these tickets. As this opens up the possibility to re-design the information system the following main research question was formulated:

*"How can the performance of the order handling process at the Royal FloraHolland flower auction in Aalsmeer be improved through re-design of the information system?"*

In this research the 'information system' is defined as the aspects involved in the planning and coordinating the process focusing on what information is used and how it is used.

The order handling process of the flower auction starts simultaneously with the auction itself. In the same order as auctioned the products are brought to the distribution area and placed in one of the buffers. In this area around 250 distributors drive around on small electro tractors. A distributor takes a STW from the buffer and drops of all transactions on the STW at designated locations for each buyer. At these locations an empty STW, referred to as buyer STW, awaits to be filled with transactions for its buyer. Once full or past the maximum forward time for one of the transactions on it the buyer STW is forwarded to the delivery, where all finished buyer STW are combined into train and delivered to the buyers location within the building. The scope of this research consists of the order handling process starting when the products leave the storage up to the point where they are forwarded to delivery.

In this research the on-time delivery performance and the productivity are the KPI used to measure the performance of the process. On-time delivery performance is the percentage of transactions that reaches the delivery step on time. This KPI is important as it gives an indication of the quality of the service delivered to the client. Currently a throughput time criterion is used which determines that the transactions should be at the delivery within two hours measured from the moment the transaction was made at the auction in order to reach the client in time. For a small percentage of the transactions the throughput time of four hours is used. The productivity of the order handling process is measured as the number of transactions processed per deployed hour in the distribution and gives information about the efficiency of the operation.

The following method is used. First literature is consulted and the process and its information system are analysed and mapped using lean manufacturing theory. Based on the findings and knowledge from literature several future state scenarios were developed to improve the performance of the process. After this a discrete event simulation model of the process is developed and validated. This model is used to test the impact of the proposed scenarios.

The analysis has shown multiple areas to improve the process on, both in the overall structure of the process as well as in the detailed organization of the process. The process is push based, in which the auction determines the workload and the planning for the distribution. As the auction pushes out transactions at a higher rate than the distribution can handle a backlog builds up. The delivery moment is based on the purchase moment of the transaction and because of this the total number of transactions created at the auction determines what performance can be achieved in the distribution process. It is also found that the distributors regularly are waiting to deliver a transaction because the drop off point is occupied by another distributor. With 1122 possible drop off points and only 280 distributors active at the same time this seems unnecessary. Also it was found that the information distributors can use to select the next task to perform is limited resulting in larger fluctuations in lead time effecting the on-time delivery performance.

To create simulation model of the process Delphi in combination with TOMAS is used. A discrete event simulation model was created that can be used to simulate the processing of a set of supplies STW using a given number of distributors. The model keeps track of the on-time delivery performance and productivity as well as several other outputs like the average lead time, the expansion factor, and waiting time of distributors.

For the validation of the model's performance operational data from Royal FloraHolland was used from the period of September 2016 until August 2017. Three data sets were developed for the validation presented as a bottom line case, a base line case and a top line case. Together with the people from Royal FloraHolland several outputs besides the mentioned KPI were selected for the validation. The model reproduces the validation cases with an accuracy of 3.2% making it a useful platform to test proposed future state scenarios with.

To improve the performance of the order handling process several future state scenarios were developed. First an ideal state was developed, based on the theory. The ideal state focuses on the added value for the client. Since this is a service process instead of a manufacturing process the quality of the service is the added value. For the ideal state the following objective is formulated: deliver what the client wants, when he wants it. To achieve this the ideal state uses a pull based structure in which a client order list triggers the planning of the physical order picking process, reasoning backwards from the delivery moment to calculate the required start of the activities.

The future states were developed based on this ideal state, but now the restrictions of the unique situation at Royal FloraHolland are taken into account. Two new planning strategies were proposed. One operating within the current setup in which the auction and order handling are connected through the throughput time criterion, and one in which the auction and order handling process are cut loose. It was found that in order to implement these planning strategies additional control was required to follow the planning and therefore the Task Assignment Control was proposed. Also to improve the process flow and minimize the waiting time the Dynamic Path Position Control was designed.

First the controls were tested individually to verify their impact on the performance. Both had positive impact on the performance and were found to be fit for use in future state scenarios. Three future state scenarios were proposed, each using both proposed controls and making use of a different planning strategy. The scenarios are:

- Scenario 1: Current state planning
- Scenario 2: Norm time planning
- Scenario 3: Client demand planning

The norm time planning uses the characteristics of the supplied STW to calculate the expected process time (norm time) for the STW. The required start time is then calculated using the norm time and the planned delivery time. The tasks will be processed according these

start times. The client demand planning uses the same principle to calculate the norm time and the same controls but in this planning scenario the delivery moment is no longer based on the purchase moment of the transactions but based on the moment the client wants to receive it. To enable this a time block structure is used in which all clients are assigned to a predefined time block in which their transactions will be processed. This ensures the client will receive all his products at once at a desired moment. In this scenario the actual client demand has been assumed as this was unknown. The client demand planning uses eight time blocks of 1 hour to which the clients are assigned.

The performance of each of the scenarios in the conditions of the test cases was tested using the model. The results showed that all three proposed scenarios improve the performance of the order handling process.

- **Scenario 1:**

The use of the two controllers together resulted in an improvement of both the on-time delivery performance and the productivity. The results showed that the effect of the controls is larger in the busier test cases. On-time delivery went up with 0,6%, 2,5%, and 8,3% in respectively the bottom, base, and top line test case compared to the current state model. Similar increase is seen in the productivity as the results were and increase of respectively 0,6%, 2,5%, and 4,1%. Further analysis indicated that the task assignment control improves the on-time delivery directly. The dynamic path position control reduces the waiting time, causing an increase in the productivity and a decrease in lead time with higher on-time delivery performance as a result.

- **Scenario 2:**

In the second scenario the current state planning is replaced with the norm time planning. This scenario also improves the performance on both KPI, however the norm time planning has limited effect on this. The results are comparable to the results of scenario 1. The on-time delivery is now slightly higher with 1,0%, 3,0%, and 9,1% for respectively the bottom, base, and top line test case compared to the current state model. The improvement to the productivity is slightly lower with respectively 0,4%, 2,1%, and 4,0%.

- **Scenario 3:**

The client demand planning used in the third scenario results in a significant increase of performance in all three test case. The on-time delivery is increased with 4,0%, 7,6%, and 14,9% in respectively the bottom, base, and top test cases compared to the current state model. The productivity is improved with respectively 3,8%, 4,1%, and 5,0%. The on-time delivery is now close to perfect, as a result of this planning, and this is achieved with less resources in the distribution.

In the proposed scenarios the information system was re-designed to improve the performance of the operation. The results from the simulation tests show that each of the scenarios improve the performance on both on-time delivery and productivity. Client demand planning provides a structure in which the performance is less dependent on the workload provided by the growers. The controls both are essential for the results achieved in the scenarios. The task assignment control enables execution of more detailed planning while the dynamic path position control minimizes the waiting time for distributors. The client demand planning would not function without a dynamic path position control as the layout of the path positions changes completely every hour. The scenarios show different ways of how the process performance can be improved through re-design of the information system.

Based on the results it is recommended to further develop a process as proposed in scenario 3. Disconnecting the auction from the order handling process allows to control and plan the order handling process better. The client demand planning has shown to be beneficial to the performance of the order handling process and the service towards the clients. Further research is required to determine how such disconnection can be achieved and what

the implications of this will to the processes bordering the order handling process. Also the client demand for has to be investigated. Further it is recommended to develop the controls as proposed. Both controls improve the performance, individually and combined. The use of the dynamic path control could result in higher workload throughput to the delivery process and future research should be performed on this controller to minimize this. However, this also depends on the planning used in combination with the control.

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# Abbreviations

Buf	Buffer-out (time stamp)
BufIn	Buffer-in (time stamp)
CTFS	Transfer logtra (time stamp)
DLT	Throughput time
FiFo	First in first out
KoWaDi	Link-Trolley-Distribution
KoWaLa	Link-Trolley-Load
KPI	Key Performance Indicator
LDA	Logistical Services Supply
LDK	Logistical Services Buyers
Logtra	Logistical Transaction
LO	Logistical Operations
STW	Standardize Trolley
Veil	Purchase (time stamp)
Wis	Forward (time stamp)



**I**

Define



# Introduction

This thesis project is conducted at the cooperation Royal FloraHolland Aalsmeer and investigates how re-design of the information system can play a role in improving the performance of a logistical process. First problem definition definition is introduced followed by the research objective. After this the cooperation and the flower auction process are introduced.

## 1.1. Order Handling at Royal FloraHolland

Royal FloraHolland has long been a dominant player in its market as it brought supply and demand together efficiently. However, over the past years the market has changed. Internet has made it easier for growers and buyers to get in touch directly, and competitive online platforms facilitating flower trade start to emerge. The traditional physical auction clocks are no longer the only trade facilitators forcing Royal FloraHolland to look for ways to regain competitive advantage in the market.

With the program 'Royal FloraHolland 2020' the cooperation aims to prepare itself for the future and stay a leader in the changing horticultural market. Part of this program is the 'Digital Greenhouse' working on the digitalization of services for which an online platform is being developed. Also new services are being developed, such as the possibility to buy products from storage all day round, or the auctioning of products that are still in the field at the grower.

Nonetheless it is believed that a significant demand for the clock auction will remain. Products bought at the clock auction are delivered to the buyers as quickly as possible after the moment of purchase. But currently the quality of this service is under pressure as delivery agreements are regularly not met. This creates the risk of buyers moving their businesses elsewhere.

Recent changes in purchasing behavior at the auction puts more pressure on the order handling logistics. The transactions sizes have decreased, resulting in more transactions to be processed while the total volume and the time to do this have stayed the same. This has led to a insufficient performance on delivery conform agreed lead time and insufficient performance on productivity. The norm is to deliver at least 95% of the transactions on time but at this moment a performance of around 90% is realised. Also productivity is too low as this is currently only 94% of its target.

It is found that information system used to coordinate the order handling process is insufficiently equipped to do this adequately. The coordination of the process has a static character, using a standardized time schedule not taking into account the actual workload

or fluctuations in the process. The current information system lacks the flexibility to deal with the fluctuations in the daily process.

Printed order tickets prescribe the entire route and time line for each transaction. Using these tickets is expensive and a source for errors. Therefore it is desired to discard the use of these tickets. This opens up possibilities to re-design the information system used to coordinate the process.

The objective of this research is to improve the performance of the order handling process through re-design of the information system. The 'information system' is defined as the aspects involved in planning and coordinating the process, especially focusing on what information is used and how it is used. Also where the information comes from and what it is based on is subject of this research.

## 1.2. Royal FloraHolland

Royal FloraHolland is a large cooperation of growers for the horticultural sector and dates back to 1911. At that time the growers felt the need to unite and bargain a fair price for their products and founded the cooperation. The 'Dutch auction' method, also known as the 'clock auction' method, was chosen as it allowed a quick auction of the perishable ware, and guaranteed fair pricing for both the grower and the buyer. The first flower auction was established in Aalsmeer and since 2008 this auction is part of Royal FloraHolland.

Royal FloraHolland is currently the largest of its kind. It handles 90% of all Dutch flower trade and also plays a big role in the international flower trade. Royal FloraHolland employs 2956 people and in 2016 they realised a revenue of 4.6 billion and a net income of 12.5 million. About 6000 growers sell their goods through Royal FloraHolland and over half of these growers are members of to the cooperation and have a say in the company's policy through General Member Meetings and other advisory committee's. The company also has 2493 clients, of which many are located at one of the auction facilities. [1]

The place of Royal FloraHolland in the supply chain is shown in figure 1.1. It receives products from different growers and takes care of the sorting and the delivery. The products are delivered to clients located inside the facility of Royal FloraHolland. The client can be an exporter or a wholesaler, who processes the products depending on the market they serve. The two main services facilitated by Royal FloraHolland are the clock auction and the connect service.

The clock auction Royal FloarHolland takes place on a daily basis, and can be attended at location, or digitally over the Internet. In total the cooperation operates 38 auction clocks spread over their locations in Aalsmeer, Naaldwijk, Rijnsburg, and Eelde. The clock auction starts early in the morning and all products put up for auction have to be physically present in the building as the distribution starts simultaneously. Clients will receive their products shortly after buying them so they can process them quickly.

Besides the clock auction process also 'Connect' service is offered. Connect allows growers and clients to trade directly. The grower then delivers the products at the dock of Royal FloraHolland, who will then take care of the delivery to the client located in the building.



Figure 1.1: Supply chain from grower till consumer

Clock auction and Connect service generate comparable turnover; clock auction accounted for a turnover of 2.1 billion in 2016 while connect service realised 2.5 billion turnover.

From the four locations of Royal FloraHolland Aalsmeer is the largest, both in terms of annual throughput and size. The location covers 1,3 million square meters and realised an annual throughput of 1.08 billion euro over 2016, handling almost 3.5 million trolleys of product. Aalsmeer houses ten auction clocks for flowers and four auction clocks for plants. Together on average generating over 50.000 transactions per day. This accounts for 41,7% of the total transactions Royal FloraHolland handles a day. [1]

### 1.3. Flower Auction Process

The flower auction is essentially a market place where growers can sell their products. The logistical process starts when a grower delivers its product for the auction, and ends when the sorted products are delivered to the buyers box. The process steps are shown in figure 1.2 and will be discussed in more detail in this section.

A grower registers and delivers his products before the auction starts. In the 24 hours prior to the auction the grower can deliver products to the auction and Royal FloraHolland will store them in one of the cooled storage facilities to preserve the quality. A grower must deliver the flowers on a standardized trolley called 'STW' (Stapelwagens). The department responsible for the intake and storage of the supplied STW is the 'Logistical Services Supply' or 'LDA' (Logistieke Dienst Aanvoer).

After a buyer makes a purchase at the auction the order is converted into a (logistical) transaction, or 'logtra', filling in the details required to process the order in the logistical process. Once the auction starts the products are retrieved from storage and send over to the distribution area for further sorting. This process starts simultaneously with the auction to deliver the transactions to its buyers within the agreed throughput time. Most clients agreed to a throughput time criterion of 2,5 hours for their transactions, and for the remainder of the clients the throughput time criterion is 4,5 hours.

Logistically a distinction is made between STWs based on their load. A STW with supplied unsold products is referred to as a supply STW, and a STW loaded with sold products for the same buyer is called a buyer STW. In the order handling process the supply STWs are retrieved from storage one by one after which the products on it are sorted over (empty) buyer STWs positioned at designated places in the distribution area. Once a buyer STW is full, or has reached its change time it is forwarded to the next step. These steps, from storage until forwarding, are executed by the department called 'Logistical Operation' or 'LO' for short

STW with similar destinations are accumulated before the delivery starts. Delivery is done in batches connecting multiple STW's into trains or using the automated shuttle serve the buyers located in the facility across the road. The products are delivered at the buyers box where the products are processed further. The delivery of products is the responsibility of the department 'Logistical Service Buyers' or 'LDK'.

The buyers have very different processes from here. For example a remote located buyer might only hire a transporting company that collects the products for him while a bouquet making company processes the different products straight away into bouquets for resale.

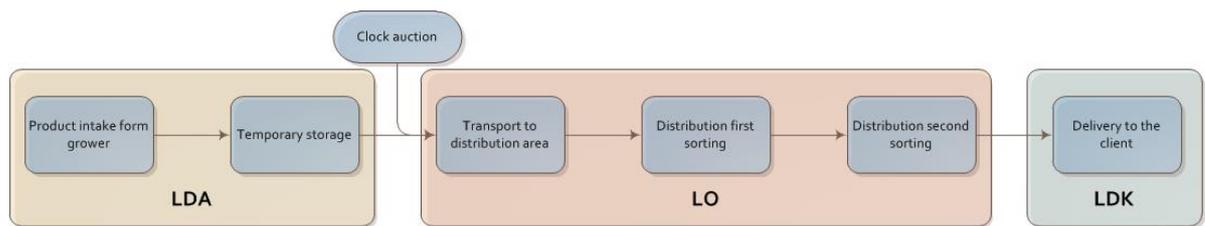


Figure 1.2: Logistic departments Royal FloraHolland Aalsmeer

# 2

## Research Design

In this chapter the main research question is introduced after which the scope will be defined in detail. The method used to conduct this research is discussed next and finally the report outline is presented.

### 2.1. Main Research Question

In this report the role information can play in the logistical process of the flower auction will be researched. In section 1.1 the problem has been defined. The objective of this research is to improve the performance of the order handling process through re-design of the information system. The 'information system' is defined as the aspects involved in the planning and the coordination of the process focusing on what information is used and how it is used. The main research question to answer at the end of the report is as follows:

*"How can the performance of the order handling process at the Royal FloraHolland flower auction in Aalsmeer be improved through re-design of the information system?"*

The 'information system' was defined as the aspects involved in the planning and coordinating the process focusing on what information is used and how it is used. The research will focus on exploring more dynamic use of information in the process to make it deal better with fluctuation and optimize use of resources in order to improve the performance. This will be done by re-designing the way the the process is executed and coordinated.

### 2.2. Scope

The research focuses on the flower auction process at Royal FloraHolland Aalsmeer, and on the logistics of the order handling process in particular. The scope has been defined as the order handling process, starting with the retrieval of products from storage up until the products are sorted and forwarded to delivery. These are the steps executed by the department LO as indicated in figure 1.2. The research focuses on the performance of the physical process and role the information system plays in this. Both these aspects are described in detail in the following sections. An Elaborate process description is added in appendix B

#### 2.2.1. Physical Order Handling Process

The order handling process steps span from the storage till delivery to the client. This process determines the quality of the service to the clients. A more detailed representation of these steps is given in figure 2.1.

### Cooled Storage

In the cooled storage the supplied STW with products are positioned in long rows and places on tracks. This is done accordingly the planning of the auction. Each product belongs to a certain auction group, and each group is auctioned at a particular clock in a particular order. The order in which the products are auctioned within each group is chosen randomly shortly before the auction starts to give grower equal chances at the more profitable positions in the auction groups. Once the auction starts products are transported to the distribution area using a automated chain conveyor in the ground, onto which a STW can be hooked.

### Distribution Buffer

Figure 2.2 shows the central distribution area to where the supply STW are transported. The numbers in this figure indicate the steps in the process and the colored areas are designated areas for specific steps, and correspond with the numbering in figure 2.1. The depicted area is about 300 meters long, and 100 meter wide.

At number (1) in figure 2.2 the supply STW enters one of the distribution buffers. There are five buffers and each is connected to a single chain conveyor that supplies it with a continuous stream of STW. Each buffer consists of 12-15 separate tracks over which the STW are sorted according difficulty of the load and destination. The floor is slightly tilted in the buffers so that STW run down automatically, creating FiFo in each track. Just before the STW enters the buffer a printed ticket is added for each order on the STW. This, together with the rest of the information system, will be explained in more detail later on.

### Pick STW from Buffer

The supplied STW is picked from the buffer at number (2) by a distributor riding on a small electric tractor. The distributor selects a STW from one of the buffer tracks and connects it to the tractor. Now it can drive around with the STW and deliver all the transactions on it to the right locations. The orange highlighted area in figure 2.2 indicate the drive lanes. Using the printed ticket and the instructions received through a voice headset system the distributor knows what to do, and drives to the right location.

### Drop Off or Transfer to Buyer STW

Number (3) shows dropping off or transferring an order to a buyer STW. The distributor is send to one of the paths in the distribution area, highlighted in green. In each path around 20 positions are marked where (empty) buyer STW. The distributor is send to one of these positions specifically to transfer the order onto the buyer STW. Multiple orders for the same client are place on the STW until it is full, after which it is forwarded to the next step.

when the last order on a supply STW is large enough it is not transfered onto a new STW, but dropped off with the STW at once. This is done at the and of the path and forwarded to the next step immediately. Such a transaction is called a 'Drop off transaction' or a 'restkoop'. Regularly entire supply STW are bought at once. These are dropped off in the same way and called 'single buy' or '1-koop'.

### Forward to delivery

After a buyer STW is forwarded to the next step it is sorted on the client's address. STW with similar destinations are accumulated. This is partially done with the layout of the paths as clients are assigned to paths depending on their address in the building.

At the areas highlighted in red, like at number (4a) in figure 2.2, several tracks lay in the ground. Each track is assigned to an area in the building and the buyer STW for clients based in those areas are accumulated in the designated tracks. A worker, the 'path manager' managers this sorting manually. He also manages the path area belonging to these tracks, looking for filled STW, or transactions that are over time. If such a transaction is present the STW it sits on is forwarded, also when the STW is not filled completely. The difference between number (4a) and (4b) is the delivery process it is connected to as is explained next.

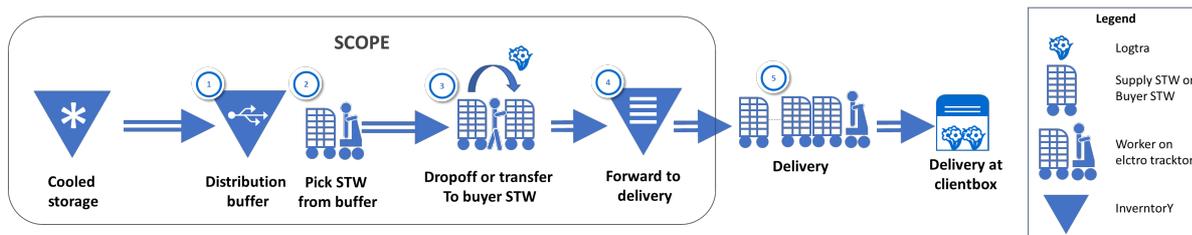


Figure 2.1: Process steps from storage to client delivery

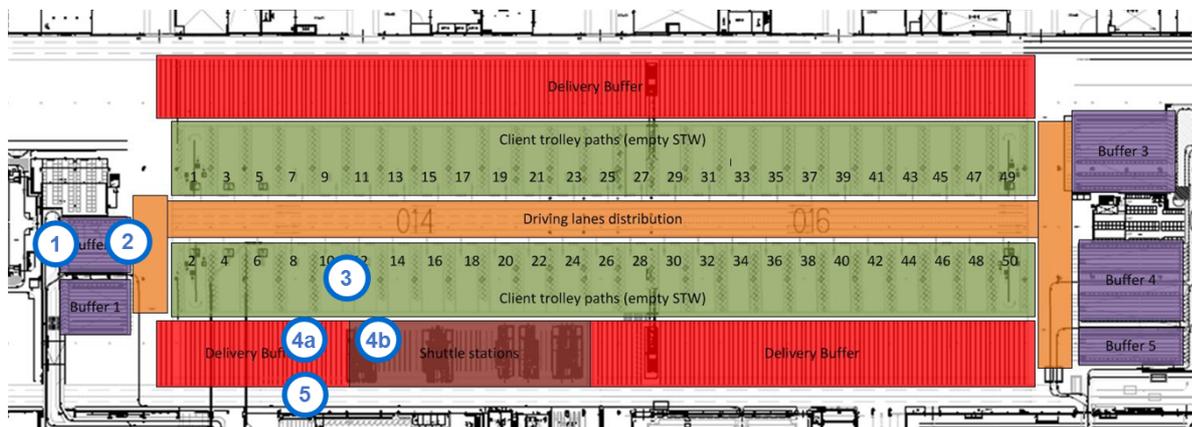


Figure 2.2: Layout of the central distribution area at Royal FloraHolland Aalsmeer

## Delivery

Although this step lies outside the scope it is shortly mentioned to create a better understanding of the total process. The delivery can be performed by an automated shuttle. The STW's are fed into the shuttle in long trains. The shuttle system will automatically scan the STW for its destination and load it onto a shuttle to transport it there. The shuttle is used for all deliveries to cross the road at the so-called location 'south'. In figure 2.2 number (4b) indicates the shuttle stations' locations. A shuttle station is also present in the client's box and the delivery is performed automatically.

The rest of the buyer STW is delivered by combining multiple STW into a train and driving it to the client boxes. Number (4a) indicates an area where the buyer STW are collected for delivery. At number (5) a LDK driver picks up these buyer STW for delivery. Figure 2.3 shows a few STW connect in train figuration.

The LDK driver drops the STW for a client at their box. A client connected to the shuttle will receive the STW automatically.

## The 'Stapelwagen'

The 'stapelwagen' or STW, shown in figure 2.3, is a standardized piece of equipment used for the transport of the flowers. Flowers come in the buckets or 'fusts' as in the figure, or in boxes when they are kept dry. The size of the STW is standardized so that it can efficiently be packed with the fusts or boxes. The number of decks on an STW can be adjusted to the height of the products. These STW are used throughout the process and can also be used at the growers and to the clients' locations.

These STW have several attributes that allow easy handling or transport in the process. As can be seen in figure 2.3 the STW can be connected into trains which allows moving them in bulk. A STW can be connected to a small electro tractor as is done for the distribution.



Figure 2.3: Standardized trolley 'Stapelwagen' or STW

A rod on the STW can slide down as well, making it possible to place the STW in a track in the floor. This is used in storage and in the buffers to ensure the STW stays in a particular track. These tracks are passive and only guide the STW if it rolls or is pushed.

Chain conveyors are used for the transport of STW from storage to the buffers. The chain conveyor runs in a track in the floor and the STW can be connected to this by pushing the rod into the track.

Besides these features regarding transport possibilities the STW's all have a unique ID number that allows tracking them in the process. When there are products on an STW these are linked to the STW ID which allows tracking of the products as well. The ID can be found on the STW in several ways.

First of all the STW has two places where a barcode is tagged to the frame. Both are standardized and easily accessible with scanners. Secondly RFID tags are placed underneath the STW that allow it to be detected by antennas that lay along the chain conveyors. There is a low frequency tag and a high frequency tag on every STW. However, the low frequency tag is the only one that is being used in the current process.

### 2.2.2. Order Handling Process Information System

The information to execute a transaction is defined right after the purchase is made at the auction. The time schedule and the route are determined based on standardized planning and a fixed layout of the distribution area. This information is printed on a ticket for each transaction when a STW on the chain conveyor passes over a RFID antenna connected to a printer (figure 2.4). The tickets are placed on the STW manually. Just before entering the buffer at number (1) the RFID tag is read again, triggering an automated sorting mechanism which directs the STW off the chain conveyor into the right buffer track.

At (2) the distributor takes a STW and scans it using a hand scanner. This starts the voice dialogue which is a system that communicates instructions for the execution to the distributor via a headset. At (3) the logtra is transferred to a buyer STW. Via the voice system it is verified the distributor performs the act correctly and after this the order ticket is stuck onto one of the transferred fusts.

As the buyer STW is forwarded it is scanned to signal this step and it is placed in one of the tracks ready to be picked up for delivery. The delivery chauffeur scans the STW again when picking it up and when dropping it off at the client to register the actions.

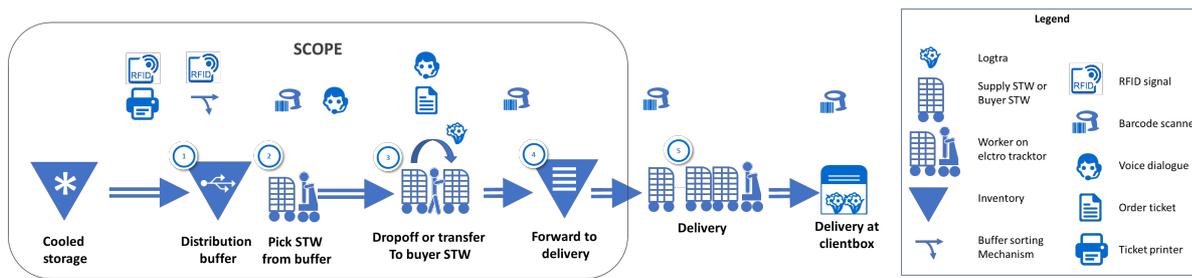


Figure 2.4: Process steps and information system

## 2.3. Research Design

This section will provide the structure for this research and for the research report. Sub questions will be introduced providing a guideline for the research. Also the outline of the report will be given, describing the content of each chapter.

### 2.3.1. Part I: Define

First the problem will be defined. Next literature will be consulted to create an overview of the available knowledge on the subject and get knowledge about the functioning of similar processes. The following sub research question will be answered using literature:

1. What can be learned from literature on distribution center logistics, order picking, lean manufacturing for logistics and the role of informations in a logistic system?

Literature will be studied to gain insight in the functioning of the processes. The flower auction process at Royal FloraHolland is a unique process that is not commonly seen. However, it does show similarities with distribution center logistics and warehousing processes making it relevant to study literature on these more common types of processes. Literature on order picking processes will be studies investigated as well as the order handling in the flower auction process is essentially an order picking process.

Royal FloraHolland tries to incorporate 'Lean Manufacturing' or 'Lean Thinking' in the way they look at their processes and use corresponding theory to improve their performance. The appropriateness of Lean Manufacturing in the context of the earlier mentioned processes will be studied as well.

The second subquestion is used to find out in what ways information provision can be used to influence the performance of logistical processes. The literature will be consulted to find out what is already known on this subject.

### 2.3.2. Part II: Measure & Analyse

The second part is measure and analyse. In this part the current state will be analysed to better understand the processes and how they function using the following subquestions:

2. What is the performance of the current order handling process?
3. How does the information system effect the performance?

Fist the performance of the current order handling process is analysed and mapped in detail. By zooming in on specific steps the influence of these on the performance becomes clear and gives an understanding of the functioning. It will also be defined what KPI are relevant to measure the performance of the process.

Next the specific role of the current information system in the process is examined. How this influences the performance is analysed with respect to the selected KPI.

The understanding of the process and the analyses performed a current state model will be designed and build. This model aims to simulate the order handling process as it functions in the current state, so that it can later be used as a test environment for proposed future state scenarios. To ensure the model represents the current state the model will be validated and the outputs will be verified.

### 2.3.3. Part III: Design & Evaluate

The final part is Design & Evaluate. In this part the gained insights and knowledge will be used to design future state scenarios that improve the performance of the order handling process. The following sub research questions will be answered to achieve this.

4. How can information be used to influence the performance of the order handling process?
5. What impact do the design options have on the performance of the order handling process?

First the gathered knowledge will be consulted to design the digital information system, looking at what information will be provided at which steps, and how will the information be used. From the concepts scenarios will be made for further testing using the model. By implementing each of the scenarios in the current state model and measuring the performance the impact of the propositions can be quantified.

The results from the simulation model will be evaluated and compared to come to conclusions about their influences. Finally the answers to the sub research questions will provide the information that is required to eventually answer the main research question. The results will be discussed and recommendations for future work will be given.

## 2.4. Report Structure

The research as described in the previous section is divided into parts, each part contains different chapters. An overview of these chapters and their content is provided below:

- **Chapter 3: Literature Study**

This chapter will provide an overview of the available literature on the subject. Both the functioning of similar processes as well as the role information in this functioning will be discussed as gaps in the literature are identified.

- **Chapter 4: Current State Analysis**

A thorough analysis of the current state process will be provided here, using lean manufacturing tools. Specific steps in the process will be discussed in detail regarding the influence they have on the performance of the whole.

- **Chapter 5: Current State Modeling**

The design and development of the current state model is discussed in chapter 4. An overview of the functionalities and the input data will be given. Also validation and verification of the model is discussed in this chapter.

- **Chapter 6: Future State Design**

This chapter is dedicated to the developed future states and what these aim to achieve. Different scenarios are discussed and motivated. Also the implementation of the scenarios in the model is discussed briefly.

- **Chapter 7: Results**

In this chapter the results from the experiments will be presented and discussed.

- **Chapter 8: Conclusion and Recommendations**

The final starts with the conclusions drawn from the results, followed by a discussion on the experiments with the model and the results. Also recommendations for future research will be given.



# 3

## Literature Study

### 3.1. Distribution Center Logistics and Order Picking

The order distribution and delivery process at Royal FloraHolland has many characteristics that are not commonly seen in most warehousing or distribution center operations making it a unique operation. However, there is also lots of resemblance between the operations as well. Therefore literature about DC logistics and warehousing will be reviewed. Order picking is particularly interesting to investigate as it is part of warehousing and DC operations as well as it is part of the Royal FloraHolland clock auction process.

A distribution center can often be seen as the link between the supplier and the customer. This is also the case for Royal FloraHolland, where the goods are supplied by the growers and, after auction, have to be delivered to the customer. To get the right products to the right customer order picking has to take place. In this section relevant background of distribution centers and order picking will be discussed.

#### 3.1.1. Warehousing and Distribution Center Logistics

The basic process consists of receiving goods at one end, accumulation and sorting in the middle, and shipping the right goods to the right customer on the other end. In addition also storage of goods until a customer requests them can be part of the process. The term 'warehouse' is used if the main function is buffering and storage. If additionally distribution is the main function, the term 'distribution center' is commonly used, whereas 'transshipment', 'cross-dock', or 'platform' center is often used if storage hardly plays a role [5]. In figure 3.1 typical warehouse functions and flows are illustrated. Depending on the desired functionality of the facility the different aspects can present in smaller portions or not present at all. The clock auction logistics at Royal FloraHolland is most similar to a distribution center, with the unique feature that each day all received products are shipped out again.

The service that typical customers like to receive from a warehouse or distribution center has to do with the quality and speed of the delivery. High levels of internal service can have a significant effect on the external and supply chain performance [23]. When looking at the internal operation the service level is composed of a variety of factors such as average and variation of order picking delivery time, order integrity, and accuracy [5]. This shows that the order picking process is of great importance for the quality of service to the customer.

Warehousing is becoming more and more a critical activity in the supply chain to outperform competitors on customer service, lead times, and costs. However, if warehousing is to be a source of competitive advantage, then implementation of a warehouse management system (WMS) is a necessary condition to achieve efficiently the high performance of warehousing

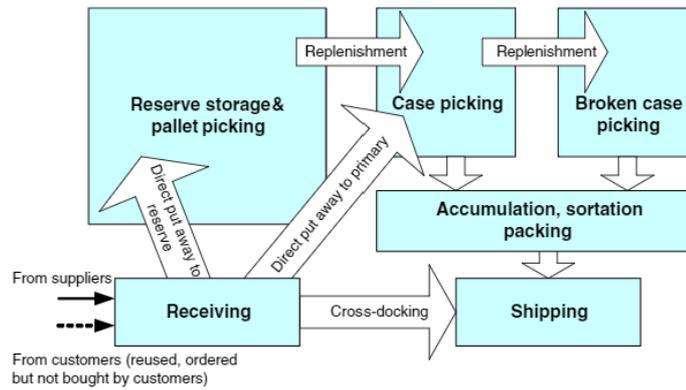


Figure 3.1: Typical warehouse functions and flows [21]

operations required in today's marketplace. A warehouse management system provides the information necessary to manage and control the flow of products in a warehouse from receiving to shipping. [7]

Faber [7] discusses warehouse complexity and the what a WMS can do for the operation. Warehouse complexity is refers to the number and variety of items to be handled, the degree of their interaction, and the number, nature, i.e. the technologies used, and the variety of processes (including the number and variety of orders and order lines and the types of customers and suppliers). He states that the number of order lines is an explicit and an implicit measure of warehouse complexity. A complex WMS is able to optimize a warehouse using information about where each product is (tracking and tracing), where it is going to and why (planning, execution, and control). A complex WMS is able to interface with with all kinds of different technical systems (AS/RS), sorter, AGV, robots, and data collection systems). Furthermore, a complex system offers additional functionality, like transportation planning, value added logistics planning, and sometimes simulation to optimize the parameter settings of the system. In highly complex warehouses, feeding organizational actors with the right type of information and knowledge knowledge at the right time is difficult. Nonetheless, a complex warehouse requires a control structure that has a great deal of information, data and knowledge about products, processes, customers, and resources readily available. According to Faber [7] warehoused with more then 10.000 SKUs (Stock Keeping Units) or more that 10.000 order lines processed per day require a tailer-made WMS to remain competitive.

### 3.1.2. Order Picking

A sub process seen in every distribution center or warehouse is order picking. Order picking is the process of retrieving products from storage or buffer areas in response to a specific customer request, obtaining the right amount of the right products [2, 5]. This process can be organized in many different ways, depending on the characteristics of the product specifications, variety, and quantity, and determines the operations complexity. Retrieving small quantities of items from a large warehouse requires a different approach than retrieving only a few larger ones per order.

According to Goetschalckx and Ashayeri [8] and to Tompkins [21] order picking is the most labor-intensive operation in warehouses with manual systems, and very capital-intensive in operation in automated warehouse systems. In addition, Van den Berg [2] and Coyle [3] even states that between 50-75% of all operating costs in a typical warehouse can be attributed to order picking. Currently the trend is that low volumes have to be delivered more frequently with shorter response times from a significantly wider variety of SKU. This puts more pressure on the order picking process as well.

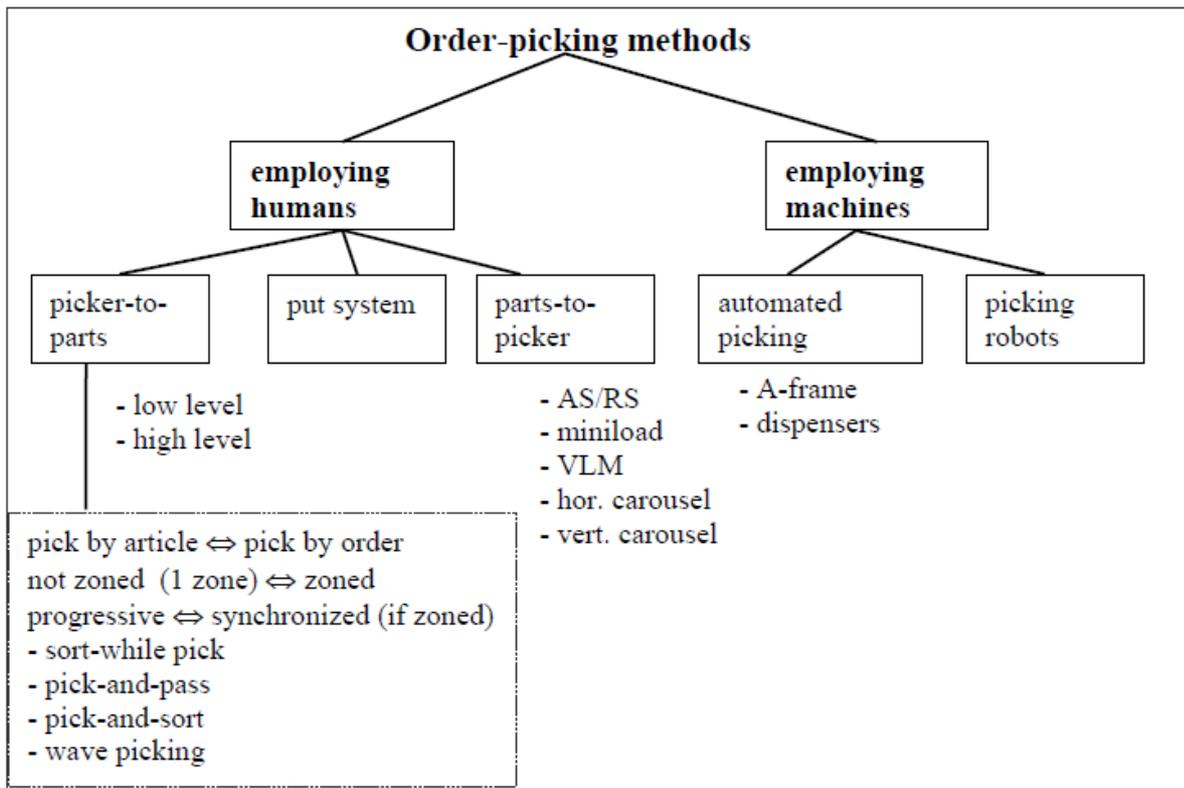


Figure 3.2: Classification of order picking systems [4]

## Order Picking Methods

A wide variety of order picking methods have been developed for different situations. In figure 3.2 different order picking methods are categorized, distinguishing between whether humans or automated machines are used.

within methods employing humans three main principles are given. The first one is picker-to-parts. This is a common seen method of order picking since it can be implemented easily. With this method the picker moves around the warehouse, visiting the locations of the required items and collects these in a bin. Different variations or aspects are shown, but these will not be discussed into great detail. Relevant methods or aspects are selected and briefly discussed.

In a parts-to-picker system this process goes the other way around. Automated storage and retrieval systems are used to provide the parts to the picker. This requires automated storage and retrieval systems, using mostly aisle bound cranes that retrieve one or more unit loads and bring them to a pick position. Here the picker takes the required amount of pieces after which the remaining load is stored again. [6]

Put systems, also known as order distribution systems, consists of a retrieval and distribution process. First, items have to be retrieved, which can be done in a part-to-picker or picker-to-parts manner. Second, the carrier (usually a bin) with these pre-picked units is offered to an order picker who distributes them over customer orders ('puts' them in customer cartons). Put systems are particularly popular in case a large number of customer order lines have to be picked in a short time window (for example at Amazon Germany warehouse, or flower auctions). [4]

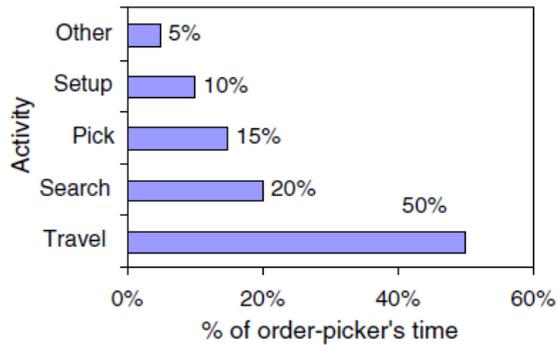


Figure 3.3: Typical distribution of an order picker's time [21]

Looking in more detail to these basic methods more variation is observed. Three aspects of the order picking methods can be looked at individually as is done by Petersen [18] while evaluating a distribution center organized in a simplistic manner. The three aspects looked at are the routing policy, the storage policy and the picking policy, and these can be distinguished often in warehousing and order picking.

### Storage Policies

The storage policy assigns each SKU to an available storage location, and generally fall into three categories. The SKUs may be assigned randomly, grouped into classes with similar SKUs that are placed in the same area in the warehouse, or assigned to a storage location based on demand volume. Random storage is widely used as this can easily be implemented, is simple to use, often require less space, and results in more even utilization of the picking aisles. Class based storage tries to group products that, for example, other need to be picked together. Volume based storage policies tries to store SKUs with a high volume demand close to the drop-off area. The last two policies mentioned often seek to decrease travel times for the order picker. [18]

### Routing Policies

Routing policies determine the picking sequence of SKUs on the pick list, with the goal to minimize distance traveled by the picker. Looking at a typical order picking operation travel time is identified as the most time consuming of all activities, as can be seen in figure 3.3. De Koster [5] identifies minimizing the handling costs as the common objective for order picking operations and states that in many cases this is represented by a linear function of travel distance. This shows the potential of a (close to) optimal routing policy

In practice both simple heuristics as well as optimal procedures are seen. Optimal procedures offer the best solution, but may result in confusing routes [19]. Heuristics often yield near-optimal solutions while being easy to use [17]. A standard optimal algorithm cannot take aisle congestion into account, while with heuristic methods it may be possible to avoid (or at least reduce) the aisle congestion [5].

### Traveling Salesman Problem

As travel time has big impact on the order picking operation routing of the order pickers and order picking vehicles is an important aspect. The objective of routing is to sequence the items on the pick list to ensure a good route through the warehouse, and can often be seen as a special case of the Traveling Salesman Problem. The problem of order picking classifies as a Steiner Traveling Salesman Problem [5, 15]. Given a list of locations, some of which

are required, and the lengths between them, the goal is to find the shortest possible route visiting each required location before returning to the origin location.

## 3.2. Logistics and the Role of Information

Optimizing supply chains is seen more and more. Instead of optimizing the local process synergies are sought with other players in the supply chains this requires more complex planning but can result in higher performance for the entire supply chain.

Planning is essential to any process, including logistical processes. Innovative planning uses as much relevant information as possible. Advanced planning and scheduling being developed for example to align capacity and material flow [20].

When optimizing a logistic system information on the systems functioning and performance is required. advanced planning strategies support the optimizing of logistics systems [13]. Planning is based on the available information. In more complex logistics systems the complexity of the planning increases tremendously. Controls can play a big role in the optimization of such systems. The use of controls allows optimization based on real time performance and data.

The use of real time information in logistics is increasing. With new technologies it becomes simpler to measure process states continuously and accurately. Real time information is crucial in logistics information systems according to Helo [9].

Coordination, planning, and control all can help contribute to a higher performance of a process. However, planning in advance is only possible if there is enough certainty. In less predictable processes static planning will fail. Controllers can be used to deal with such uncertainties acting based on real time data and making adjustments to the process based on this.

## 3.3. Lean Manufacturing

To be able to improve any logistical process a proper analysis of the current situation and organization is required. Lean manufacturing offers tools to analyse a process and to find areas in the process to improve on. In this section Lean manufacturing, and its applicability for this thesis project will be discussed, focusing on the available tools to analyse the process at Royal FloraHolland.

Lean Manufacturing originates from Japan where Kiichiro Toyoda developed many of the lean manufacturing principles to improve the production at Toyota Motors. In essence lean manufacturing is about minimizing waste in the process and maximizing customer value. Five main principles can be found in the literature as the essence of lean [10, 12, 24]:

- Specify value
- Identify value systems
- Make value flow
- Let value be pulled
- Pursue perfection

In practice this means that the focus should lie on value adding processes, and that non-value adding processes should be eliminated or minimized. To achieve this first one could

map the current process, and use this to categorize all the process steps as either value adding, non-value adding, and non-value adding but necessary. The non-value adding steps are also known as wastes. Non-value adding wastes should be eliminated, and non-value adding but necessary wastes should be minimized [11][24]. Generally seven types of waste are identified and these wastes are captioned by the seven letters in Tim Wood:

- Transport
- Inventory
- Motion
- Waiting
- Overproduction
- Over processing
- Defects

Many principles from lean manufacturing have proven to help understand and improve manufacturing processes.

### **Value Stream Mapping**

To be able to identify wastes the process has to be analysed. Value Stream Mapping (VSM) is a method to do so and is built on the principles of lean manufacturing. Value Stream Mapping focuses on dissecting the process in smaller steps and identifying the value stream. Tim Wood can be used to assess whether a step is waste or not. Also data of for example throughput times, waiting times and volumes can be added into the VSM. There are different VSM tools available, all focusing on the different aspects of a process and different characteristics. First the basic VSM will be explained, after which additional VSM tools are discussed.

The first step of VSM is to create a current state map, showing the process as they are at the moment. This can then be used to analyse the process and identify wastes. This analysis will then be used to redesign the process in order to eliminate as much waste as possible. This will result in the future state map, showing the redesigned situation.

To draw a VSM often standardized symbols are used to indicate different players in the process. Often not only product flow is depicted, also information flow is drawn.

#### **3.3.1. Supply Chain and Logistics**

Lean manufacturing is widely applied in many different industries. The basics, as has just been introduced, is tailored for manufacturing processes as it originates from the production industry. However, the essence of lean can be applied in a much wider field as this is about minimizing wastes and maximizing customer value. To apply lean thinking to logistical processes specific extensions have been developed, to allow identification of typical wastes in these processes.

According to Martichenko [16] lean can offer the supply chain a lot of opportunity and wealth that is not being used yet. To make the lean principles better applicable to logistical processes he reformulates the traditional seven wastes as follows:

- System complexity - additional, unnecessary steps, and confusing processes
- Lead time - excessive wait times
- Transport - unnecessary movement of product

- Space - holding places for unnecessary inventory
- Inventory - inactive raw, work in progress, or finished goods
- Human effort - activity that does not add value
- Packaging - containers that transport air or allow damage

The focus should lie on creating harmony between the different processes in the supply chain, ensuring they work well together. One of the key principles to achieve this is the use of pull systems. Also collaboration and process discipline is mentioned as key principle to achieve such harmony.

Hines et al. [12] look into lean manufacturing for warehousing and Distribution Environment and also come up with an adjusted set of wastes to minimize. Hines et al. introduce twelve wastes of which the first seven wastes are comparable to the ones given by Martichenko combined with five new ones. These ones also include overhead and other macro factors. This set of wastes look as follows.

- Doing things too early
- Waiting or delay
- Conveyance
- Inappropriate processing
- Unnecessary inventory
- Unnecessary ergonomics
- Discrepancies or errors
- Power and energy
- Human potential
- Excess pack(aging and other environmental pollution
- Unnecessary overhead (including training)
- Inappropriate layout

### 3.4. Synopsis

With the information gathered from literature the following sub research question can be answered:

- *What can be learned from literature on distribution center logistics, order picking, lean manufacturing for logistics and the role of information in logistic systems?*

Literature provided insight in how systems similar to the flower auction order handling process function. It is found that any order handling process typically has high wastes in its process and limited added value due to the nature of the process. Compared to a manufacturing process nothing is produced. The service provided by delivering the correct products on an agreed moment is often seen as the value added in such process.

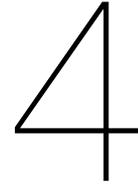
Multiple techniques to analyse a logistic system seen from a lean point of view have been discussed. As logistic processes behave differently compared to manufacturing processes some of the tools are elaborated or adjusted to be better applicable. This provides specific way to look at the process to analyse. Lean manufacturing principles are applied on logistic processes more often, stimulating the development of specific lean tools for this application.

Information is essential to any (logistical) process as it is used to coordinate and plan. Information can be used to coordinate resources better improving performance. Depending on the process many different controls can be used to improve process flow. Often real time information is essential in attempts to optimize a process.

# II

## Measure & Analyse





# Current State Analysis

This chapter will discuss the performance of the current state process. First relevant KPI will be selected after which the performance on these KPI is assessed. The performance of single steps will be analysed as well to get a detailed overview of the functioning of the process. A detailed description of the process is added in appendix B.

## 4.1. Key Performance Indicators

The main KPI's that will be used to measure the performance are the on-time delivery percentage at [Wis] and the productivity. The on-time delivery percentage is important as it is directly linked to the quality of the service towards the clients as each client is promised delivery within a fixed time from the moment of purchase. The productivity has influence on the lead time and thus the on-time delivery performance and tells a lot about how well the process is organized and executed. Both KPI's are used by Royal FloraHolland to monitor the entire process from dock till door, and in more detailed levels the same KPI are used for the separate departments or process steps as well.

### 4.1.1. On-Time Delivery

One of the main KPI's is the on-time delivery at time stamp [Wis]. This KPI is referred to as on-time delivery throughout the rest of the report. The on-time delivery is measured as the percentage of logtra that move from the auction moment (time stamp [Veil]) to the moment the logtra is forwarded (time stamp [Wis]).

A predefined time schedule is used for every logtra as displayed in figure 4.1. This schedule is used to determine if a logtra has been delivered on time and is referred to as the through put time criterion. The majority of the clients expect their products to be delivered within 2,5 hours from the moment the purchase was made. Some clients agreed to a lead time of 4,5 hours. This group of clients is responsible for about 10% of the daily transactions processed in the central distribution area. The step time is measured at several steps along the way, and combined these make up the lead time.

The time schedule depicted in figure 4.1 shows how each step may take. Also the utmost time a logtra must have passed a certain time stamp is included. Notice that not all time stamps are included in the time schedule. All logtra get the same time schedule up to the [Buf] time stamp. After that moment a distinction is made between the 2,5 hour logtra and 4,5 hour logtra. This allows more time for a logtra to wait in the path for more logtra, resulting in better filled buyer STW.

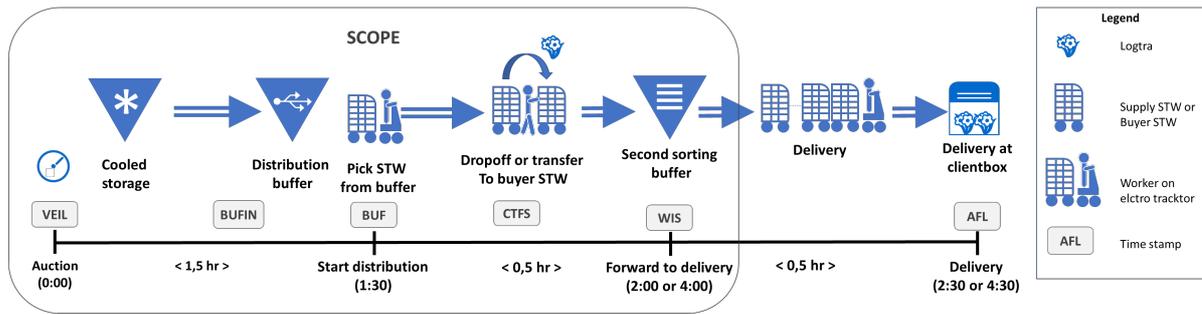


Figure 4.1: Logtra time schedule per process step

This KPI is measured as the percentage of logtra delivered on time at [Wis]. The number of transactions delivered on time consists of both the 2.5hr logtra and 4,5hr logtra are included in this KPI, measured against their own time scheme (4.2). According to the norm at least 95% should be delivered on time.

Occasionally on-time start at [buf] (Or on-time buf) is used as well. This is calculated in the same way as the on-time delivery [wis] is, although now [Wis] is replaced with [Buf]. This is seen as the start moment of the distribution step. Also the term lead time is used often. This indicates the time it took a logtra to come from [Veil] to [Wis] as this is the process that is investigated in this report.

$$\text{On-time delivery [\%]} = \frac{\# \text{ logtra on time at [Wis]}}{\text{Total \# of logtra at [Wis]}} \quad (4.1)$$

$$\# \text{ logtra delivered on time} = \# \text{ 2.5hr logtra on time} + \# \text{ 4.5hr logtra on time} \quad (4.2)$$

#### 4.1.2. Productivity

For the department LO, taking care of the distribution, productivity is measured by dividing the handled logtra by the hours deployed in the process 4.3. For the other departments this is calculated slightly different. As they handle either supplied STW or buyer STW instead this would replace the number of transactions in the formula.

$$\text{Productivity LO} = \frac{\text{Number of transactions delivered}}{\text{Hours deployed}} \quad (4.3)$$

The hours deployed in the process can be divided over two separate groups, the fixed hours and the variable hours. The fixed hours are constant and do not change depending on the amount of logtra to process. The variable hours change depending on the work load expected.

Often a percentage is used to show what the productivity is compared to the norm. This also allows to calculate the productivity of the entire as the individual departments use slightly different calculation methods.

#### Current Performance

In figures 4.2 and 4.3 the on-time delivery performance up to the delivery, the end of distribution and the start of distribution is given. The yellow line represents the weekly performance, and the red line the average for 2017 up to that week. The average delivery performance in 2017 until week 36 lays between 81% and 86% for all three checkpoints, well below the required 95%.

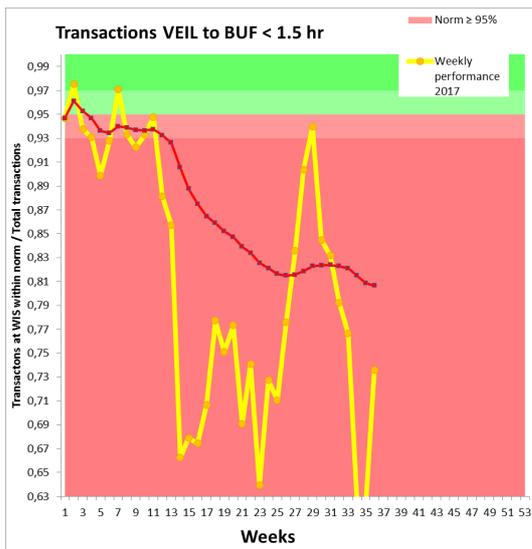


Figure 4.2: On-time BUF; auction to BUF

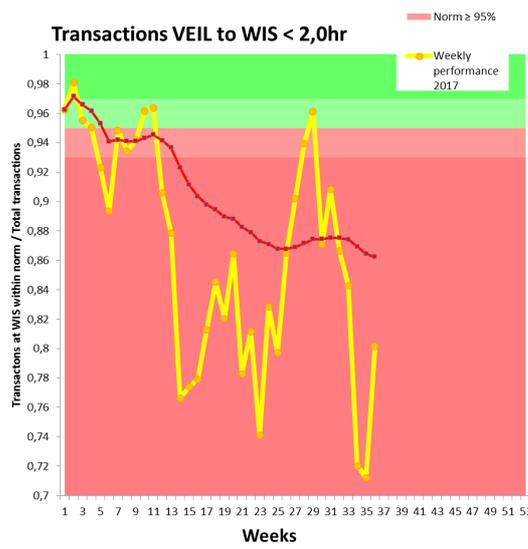


Figure 4.3: Lead time performance; auction to WIS

Also the productivity of the process is low as the average over 2017 is only 94%. Looking at the department LO specifically the productivity is 91% for the flower process.

To be able to improve these figures more thorough analysis of the process steps is performed.

## 4.2. Current State Analysis

The current state process was analysed using different tools and techniques. A swim lane was made to create a better understanding of the process and the relations between different sub processes. A value stream is created to analyse the lead time and the process steps. Also Tim Wood for logistic systems was used to structure the analysis of wastes in the process. The findings are discussed in the following sections.

### 4.2.1. Swim lane

A swim lane (page 4.2.3) of the current state process was made to create a detailed overview of the physical process and the information flow to support it. The time stamps are included in the swim lane to help navigate it. The physical processes follow each other up, but are separated by a buffer or other station where products sit idle.

The current state swim lane helps to understand the process, and how the information is used in the process.

### 4.2.2. Value Stream

Also a value stream map of the process from storage until delivery was made (figure 4.4) including a time line. This shows that the process time of a single transaction is 25 minutes on average, while the lead time is 107 minutes, measured from the moment the order is placed until it is delivered. This shows that in between processing steps the product is waiting for 82 minutes on average. The start of the physical order handling process, when the transaction is taken from the cooled storage, is on average 47 minutes after the order has been placed.

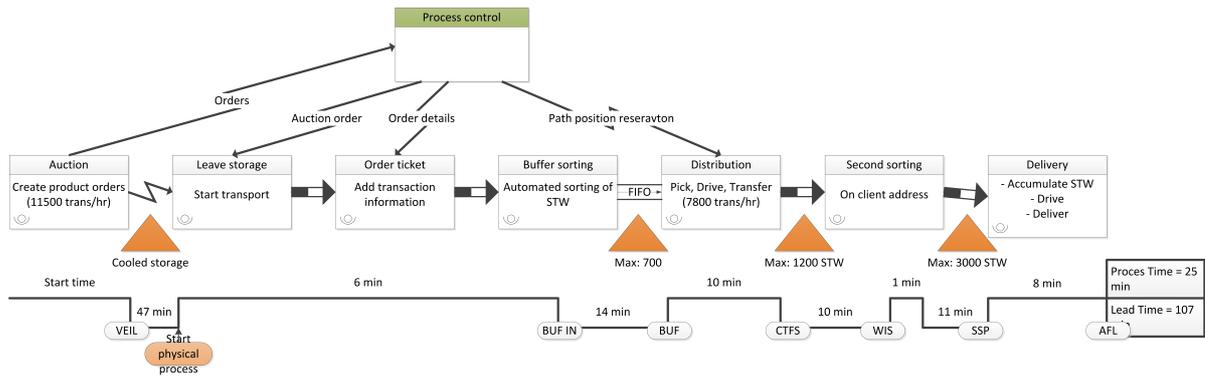


Figure 4.4: Value stream map from storage to delivery

The process time is taken as time at which the product is actually moving. One can argue that the waiting of a transaction in the path is also being processed as this allows the orders to be accumulated so proper filled STW can be delivered to the client. This reduces space required in the clients process, and decreased the amount of buyer STW to be delivered for the LDK department. However, the filling of the STW is not required for the delivery of the transactions. Also it does occur that a transactions is waiting while no more transactions are added before the transaction waiting has reached the time to be forwarded anyway. Therefore it was chosen to exclude the waiting time in the path from the process time in this VSM.

The VSM shows that on average only 23% of the lead time is actual process time, and the remaining 77% is waiting time. The largest part of waiting time occurs between the placement of the order and the start of the physical process.

### 4.2.3. Push based structure

The VSM highlights the push based structure of the operation, and the effects caused by this. Lots of inventory is waiting in the paths because it is not ready for delivery. And due to the time schedule also half filled buyer STW are forwarded. This results in more work for the delivery, and more STW are taken up in the process.

The push based structure is also fed by the throughput time criterion. This dictates the pace at which the transactions are created and virtually pushed in the process. Due to this time criterion the process performance is taken out of the control of the operators and placed in the hand of the growers and buyers. The amount of product put up for auction and the buyer's purchase behavior mainly determine more or less what the performance of the operation will be.

Order handling process flowers – Current State

Phase

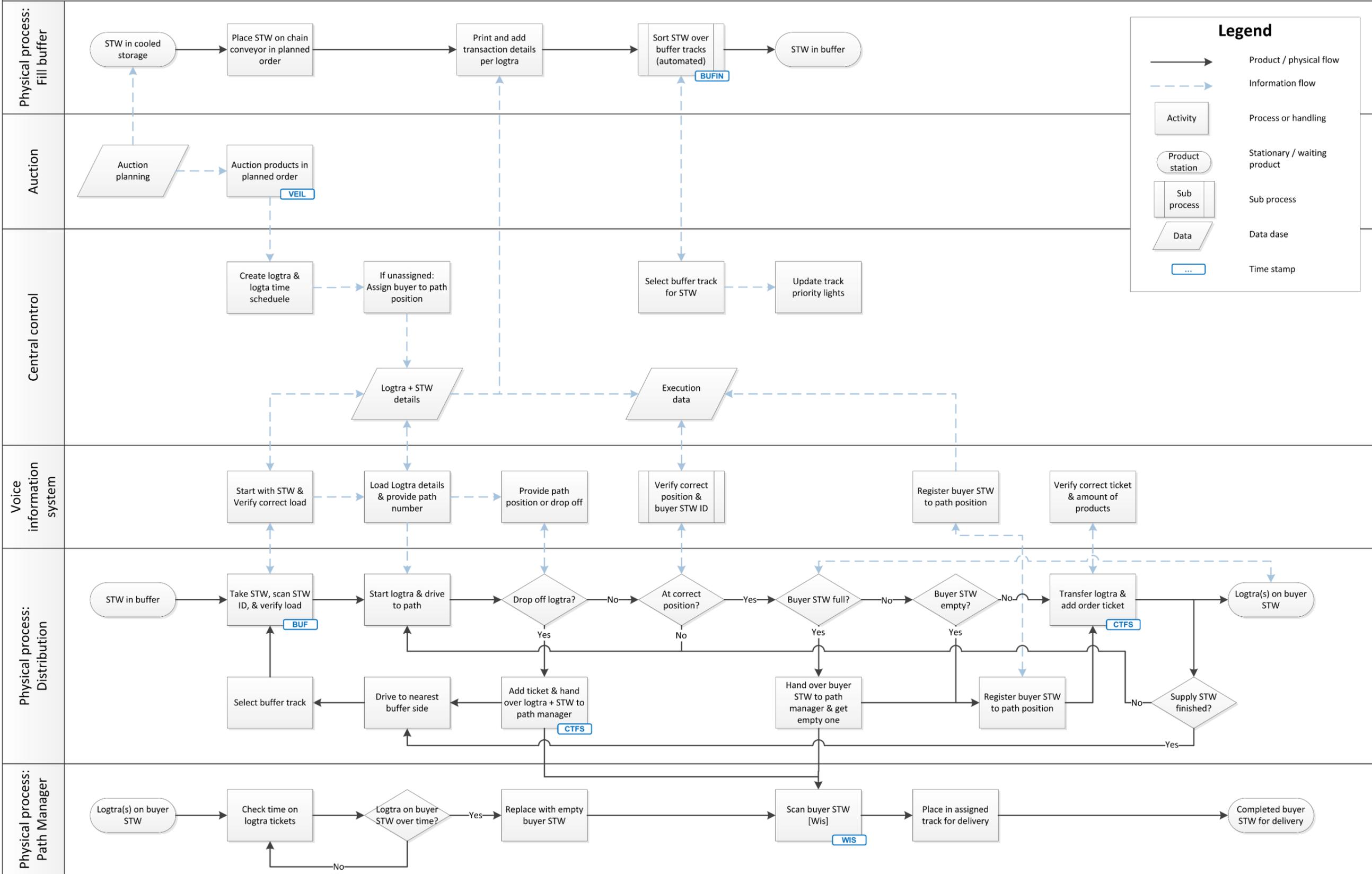




Figure 4.6: Average lead time for orders per 15 minutes auction time

### 4.2.4. Backlog Buildup

Due to a higher input rate of orders than can be handled in the order handling process a backlog builds up which causes the transactions to delay on their start time and delivery time. At the auction 11500 transactions are generated on average every hour, while the distribution can only handle 7800 transactions per hour at maximum capacity. This causes a backlog to build as can be seen in figure 4.6.

This shows that the currently used lead time criterion is of major influence on the performance. The growing backlog during the process contributed on average 44% of the total lead time and increases the dispersion as well.

The effect of the backlog buildup also becomes apparent in figure 4.7, showing the variation of achieved lead times of two separate days with different workload. The workload on this particular Monday (40827 transactions) was almost double the workload on this Thursday (19173 transaction). Also the amount of distributors on Thursday is significantly lower while the auction speed isn't lower. The amount of transactions delivered every five minutes is shown. Despite deploying more workers on Monday (267 vs 228) the average lead time increases from 1:34 hours on Thursday to 2:02 hours on Monday, mostly due to the backlog building up.

### 4.2.5. Variation in Lead Time

Variation in the lead time makes it difficult to plan the process and guarantee on time delivery. The variation in the lead time is not caused by the backlog alone. By going through the process, multiple contributions to the variation in lead times are found.

The current setup to handle the transactions is FiFo order. However, this is not achieved for several reasons. First of all, the transactions are not starting distribution in FiFo order. This happens because ten auction clocks share five supply routes, causing the products to arrive in batches of each clock, creating already some dispersion. Next, the buffer outflow adds to the variation. The supplied STW are spread over multiple tracks and the distributors seem to prefer some tracks or some STW types over others, adding to the variation. figure 4.8

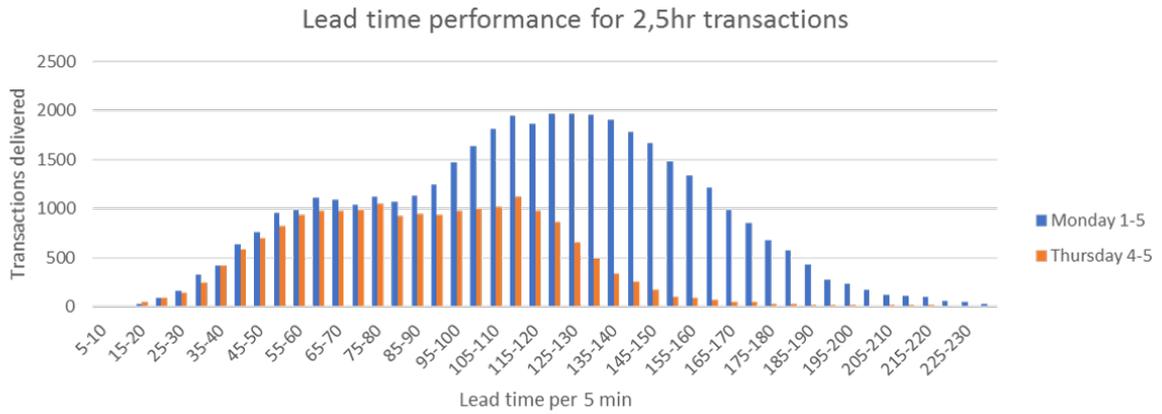


Figure 4.7: Frequency of realised lead time on a Monday and an Thursday

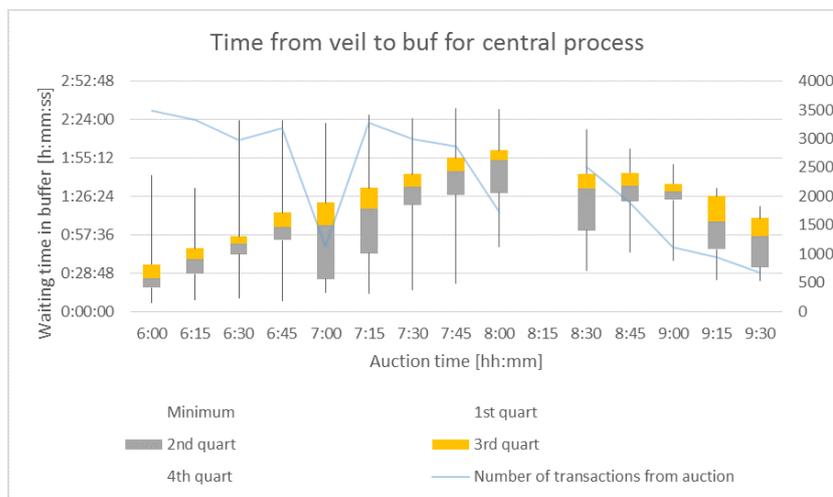


Figure 4.8: Variance of VEIL to BUF time during the day

Transactions arrive in the process on an supplied STW that can differ lot in build up. The average amount of transactions on an STW is five and the variation is large. Due to this large variation in the execution time of a transaction is seen. All transactions on an supplied STW receive the same start time. As the distributor delivers the transactions one by one, the last transactions on the route seem to take much more time in the distribution compared to the first ones, even though the time between transaction transfers is relative stable. In the current process planning this is not taken into account since all STW have to have started distribution 60 minutes before final delivery, also when there is only one transaction on the STW to transfer.

#### 4.2.6. Path Congestion

When a path is overly crowded and a position is occupied, causing a distributor to wait it is called congestion. Observation learn that the workload is not balanced equally over the paths and the path positions. It happens regularly that a certain path is crowded with distributors while the adjacent paths are completely empty. The clients are linked to a certain path and when they turn up for the auction they will be placed there until it is full; then the overflow paths are used. Each client is assigned a single position.

Some larger clients even have fixed positions and are assigned multiple positions. The idea is to spread clients evenly using the client's average purchase behavior. In this process large clients might get assigned multiple positions. This is done in two ways. The first is to fix the client to a position in the WMS, and block the position next to it so it can not be assigned to any other client. Now the path manager on the floor places a tag on the STW in the blocked position, indicating it to belong to position next to it. Distributors can now use both STW for their products.

If even more space is required, a product sorting can be created in the WMS. Products that belong to a certain auction group are accumulated on a different location than transactions from other auction groups. Multiple positions are fixed to the same client to do this. In this way the work load on average is spread better.

The downside of planning of the layout on average purchase behavior is that peaks in purchase behavior are ignored. It can still occur that multiple clients in one path all buy the same flowers. As these flowers are auctioned at the same time, they can very well end up in the path around the same time causing a peak in present distributors, causing congestion. The fixed layout during the operation based on averages does not cope with the peaks purchase behavior.

### 4.3. Role or Printed Order Ticket

The paper ticket is used to provide information about the logtra and where it is supposed to go. This paper ticket is printed and manually added to the transaction. Special quality sticker is required and several workers are employed only to place these stickers on the STW. In the order handling process the ticket itself has lost its function as information carrier as all instructions are passed on via the voice system. The path manager uses the ticket to check the forward time, however it also possesses a scanner that can tell this information. Also the barcode on the sticker is deemed unnecessary as each transaction in the system is linked to an STW and scanning the STW barcode can provide all logtra details required. Therefore the tickets can theoretically simply be discarded. This will require some changes to protocol in several steps but all equipment required to replace the tickets is already in place.

At another facility of Royal FloraHolland in Naaldwijk almost the same process is used, and here the tickets are already discarded proving this is well possible, especially for the order handling process.

As the ticket is printed including all information for the entire route it limits the possibilities to adjust its course based on real time data from the operation. This makes it impossible to adopt a more flexible structure and coordination of the operation.

### 4.4. Synopsis

The analysis of the current state process carried out in this chapter provides an answer to the following sub research question:

- *What is the performance of the current order handling process?*
- *How does the information system effect the performance?*

The previous chapter showed that from a client perspective the on-time delivery performance is most relevant. From an operational point of view productivity is valued. These two performance indicators are used as the KPI for the order handling process.

The process was analysed looking at how the process structure and coordination effects the performance, and what role the information system plays in this. First of all it was found

that the lead time grows during the process as the max capacity of the distribution is not sufficient to keep up with the speed at which orders are generated at the auction. By eliminating wastes the productivity can be improved, leading to a higher capacity for the distribution. This should result in a shorter lead time as less backlog will buildup, and eventually lead to higher on-time delivery performance and productivity. However this will probably not completely solve the problem.

Waste effecting productivity can be found in the form of congestion in the distribution area, especially in the paths. Occupied positions create waiting lines. Congestion appears in different paths at different moments throughout the day due to peaks in purchasing behavior of clients. When peak amounts of logtra for the same client arrive at the same time this results in waiting time. Both the data and observations show that with the number of clients, the number of path positions, and number the distributors congestion theoretically should not have to occur.

The time to process differs per supply STW as each STW contains a different number of logtras. This effects the average lead time of the logtra on the STW but this is not taken into account in the planning of the operation. This results in some logtra arriving too early while others are delivered too late.

Although it is planned to process the supply STW in FiFo order this is not achieved. Partially due to the supply of STW to the buffer, and partially due to the way the STW are picked from the buffer. This process is coordinated poorly as the provided information is not detailed enough.

It is also found that the order tickets are not necessary for the execution of the process as most of the communication and information provision is taken over by other means. In the few places where the ticket is still scanned this can be changed to scanning of an STW barcode also providing the relevant transaction information.

Overall the current process performance is below the norm. The on-time delivery should be increased, as well as the productivity. The analyses showed that there are several areas where improvement is possible. Planning and execution of a planning can be improved and wastes should be minimized. It is also found that the throughput time criterion is the underlying force for many of the problems and a driving factor behind the push based structure of the process. In chapter 6 different concepts improve the performance will be proposed.

# 5

## Current State Modeling

As simulation model representing the current state operation has been made, to make it possible to measure the effects of future state scenarios on the operations performance. In this chapter the process of creating a accurate model is described. First design criteria for the model are formulated and selected software is discussed, followed by a detailed description of the model's structure and parameters and variables used. After this the verification of the models implementation, the validation process, and the selected data sets are discussed.

### 5.1. Modeling Criteria

The simulation model represents the process as described earlier, from the moment of auction (Veil) until the moment a filled buyer STW is forwarded for delivery (Wis). The last step, the delivery itself, was excluded from the scope as the data has shown that this step currently functions well, and sometimes even is able to make up for lost time in earlier steps. The delay in the process has its source in the distribution step and therefore all steps between storage and forwarding are included in the simulation.

In the first place the simulation must represent the current situation accurately if it is to be a useful and reliable tool to test future state scenarios. In the second place it must provide insight in the functioning of the process and the effects of future states. To ensure the model does both some design criteria are defined, mostly regarding to the scale of the model and the outputs generated by the model.

Both the on-time-delivery performance and the productivity are important KPI of the process so these are used used as output for the simulation as well. However what is included in these figured is customized to represent a specific part of the simulation only. This research focuses on the steps form the moment of purchase to the moment a buyer STW is forwarded and follows the main flow of transactions that passes through the central distribution area. Therefore the on-time-delivery performance is measured specifically for this trajectory, excluding the last step of delivery. It was chosen to do this a the final step generally performs well and sometimes partially makes up for delays earlier in the process. Excluding this step allows a better view on the actual effect of improvements on the most critical steps in the process.

The on-time-Wis performance is measured as the total number of logtra forwarded to delivery (at Wis) divided by the number of logtra forwarded to delivery on time. This A logtra is on time if it reached this point within two hours if its client is in buyer category 0-3, and within four hours if its client is in buyer category 4-6.

Table 5.1: Inputs and outputs for simulation model

<b>Input variables</b>	Number of STW in
	Number of distributors
<b>Outputs: KPI</b>	On-time-Wis performance [%]
	Productivity
<b>Outputs: Other</b>	Split factor
	Expansion factor
	Duration auction [hr]
	Duration distribution [hr]
	Deployed distribution hours [hr]
<b>Outputs: Detailed</b>	On-time-Buf performance [%]
	Average lead time (Veil to Wis)
	Average lead time per step
	Veil to Wis dispersion [hr]

Productivity is measured as the number of logtra forwarded to delivery divided by the hours deployed in the distribution to achieve this. The deployed hours do not include the fixed work force that does not vary in size depending on the supplied amount of STW.

More detailed performance indicators are programmed as well to be able to judge the functioning of the simulation model compared to the real situation, and to study the effects of the improved scenarios. Table 5.1 shows the performance indicators that can be measured at the end of the process. The measured lead times and throughput time dispersion are measured per 15 minutes as well to provide insight in the progress of the operation. Also the development of the on-time performance is plotted.

A single run of the model simulates a days work for the central distribution area. The number of supplied STW and the number of deployed distributors per color are the only input variables for the model, as shown in table 5.1. Other variables and random distributions that define the models performance are base on operational data and cannot be altered from the interface. This was done to ensure proper verification of the model as these represent. Also the possibility to run simulation of proposed improved scenarios is included but this will be discussed in chapter 6.

The model presents the outputs in separate files that can be processed later on. These files are constructed automatically and in such way that data from multiple consecutive runs is saved in separate rows to allows simple processing of the data. Also the seed number for the random distributions is structured and documented to allow testing of different scenarios under exactly the same conditions.

## 5.2. Software

The amount of logistical transactions, or orders, that has to be processed in a single run lies between the 20.000 and 50.000. Around 250 distributors have to be active at the same time, and be able to visit on of the almost 1200 positions present in the process. The actual amount of work and distributors deployed differs a lot, depending n the case. This requires a modeling tool that allows parametric modeling, and can cope with large amounts of data.

A discrete event simulation model will be created. Discrete event simulation suits well with the modeling of this particular process, as several different processed are being per-

formed at the same time, and in different quantities, like the distributors that all perform the same task, but operate individually. By modeling each of these processes and letting them interact with each other and the environment the current state process can be represented.

Two different software packages were considered for this model which are *Simio* simulation software and *TOMAS* [22] in combination with *Pascal* using *Delphi* [14]. *Simio* is so called 'drag and drop' as many standard elements are available. These can be dragged into the simulation and connected to other elements easily which enables rapid construction of a simulation model. However, to customize elements for specific, unconventional processes takes more effort. Also the software has limited options to create a large scale process depending on a detailed set of parameters.

*TOMAS* is a discrete simulation package that can be used in combination with *Pascal* in *Delphi*, and can be used to build a simulation from the ground up. *TOMAS* provided several functionalities that make discrete event simulation in *Delphi* possible. Instead of standardized elements that can be selected from a library, each element is constructed from scratch and built to the specific needs of the user. Building a simple model is considered more time consuming compared to a drag and drop tool, however there are no limitations to the functionalities desired.

*TOMAS* in combination with *Delphi* is selected for the construction of the simulation model as this provides the freedom to create a large simulation based on a set of parameters and specific detailed inputs. Also the possibility to customize the simulation completely is required to simulate increased and dynamic control for the future states discussed in chapter 6.

## 5.3. Model Variables

To ensure the model resembles the current state distribution process properly several variables have to be used in the model. This section will discuss the variables used to create realistic behavior of the model.

The variables required are gathered from actual operational data of the distribution process at Royal FloraHolland Aalsmeer over the course of a year, running from September 2016 to August 2017. All data used is filtered to include solely flower transactions that have passed through the central distribution area. Single buy trolleys, that pass through the same buffer but from there on take a different route, are also excluded from the data.

*TOMAS* provides random functions that, when called upon return a sample from a probability density function. A uniformly, exponentially, and normally distributed function can be created. A uniform function required a start and end value between which a linear line is drawn describing the probability density. For the exponential distribution a mean value has to be given in, and for a normal distribution both a mean and a standard deviation have to be given in.

A normal or exponential distribution is often used directly, as the drawn sample for example can be used as a waiting time or a step time in the process. This provides realistic variation of the duration of certain tasks. To obtain realistic results it is important that the distributions are created based on data from the real process.

For the research purpose it is also required to be able to recreate the conditions in the simulation model. Therefore a distribution is also constructed based on a seed. This seed number indicates the start location of the random distribution sampling, and allows the experiment to be recreated, simply by starting with the same seed again.

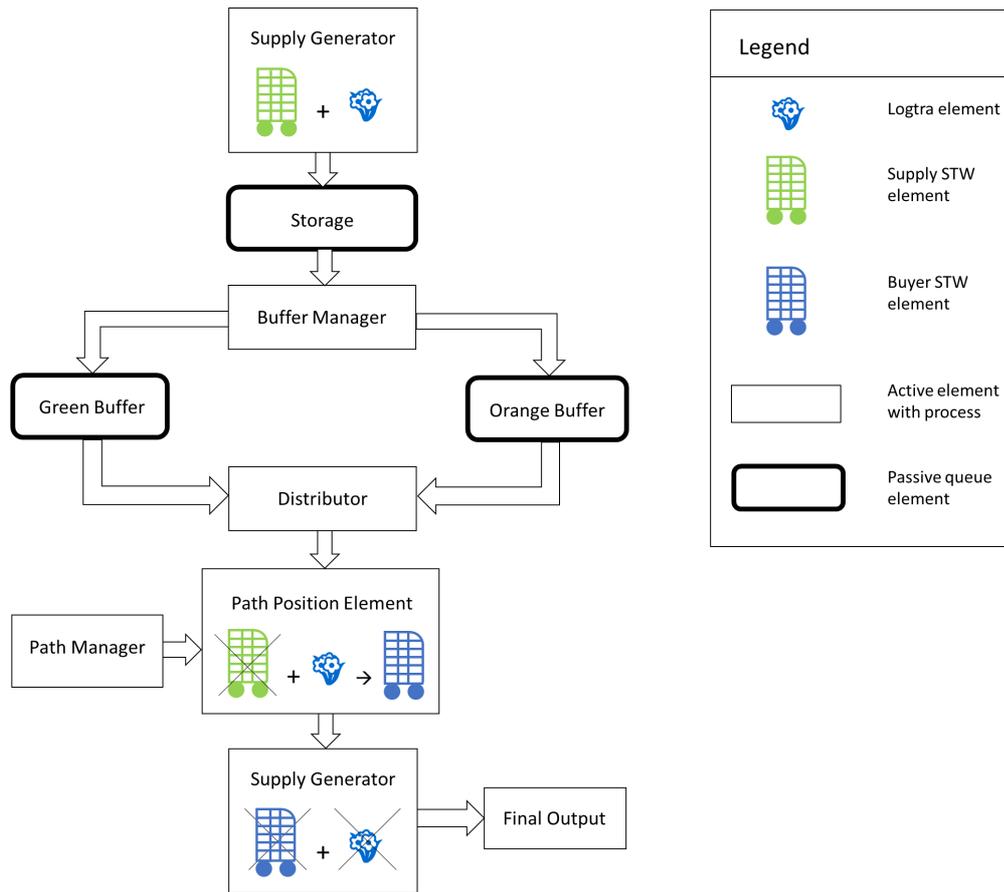


Figure 5.1: Simplified overview of model structure

*TOMAS* provides a set of seeds that guarantee independent sampling for at least 1.000.000 samples. This set was used in the model. Consecutive runs use consecutive seed numbers from the *TOMAS* seeds set. This ensures both independent sampling from the used distributions as well as the ability to recreate the exact same contritions of the experiments to test different scenarios properly.

## 5.4. Model Design

The model will consists of separate elements that all function in their own way. Some actively run a process, while others only consist of a set of unique attributes. Interaction between elements takes place depending on the events in the process of the different elements. All elements operate on the same virtual time line and actions can be programed to have a certain duration. Multiple elements can be created from the same element definition. This means that they function the same way, but depending on inputs and random distributions they take different dissensions and appear in different locations. All this makes it possible to study the interaction between different elements in a real operation.

For the model of the distribution process at Royal FloraHolland the several elements are defined and these fulfill the following tasks in the simulation model. Figure 5.1 shows the way these are setup.

### 5.4.1. Supply Generator Process

The supply generator is the element that represents the auction process and places supplied STW with products in storage, as illustrated in figure 5.1. This element houses a process in which the supply STW and logtra are created. It fills the STW with logtra, assigns clients and destinations to the logtra before placing the completed supply STW in storage. The rate at which these STW are created is defined by a curve that resembles the actual auction speed during the process. The exact construction of a STW with logtra is randomly selected, based on random distributions that represent the actual process.

#### Supply STW Element

The supplied STW will be simulated as single elements to enable them to move through the process individually. The element contains several attributes that allow storage of unique data for the particular STW, like its ID, its origin, and different timestamps. The STW element is given a TomasQueue, called freightset to allow it to carry multiple other elements with, representing the logtra.

#### Create Supply STW Element

A Supply STW element is created at the start of the repeating process of the supply generator. At this moment it is given a serial number as its ID, and a time stamp as the time of auction. Next the number of logtra on this particular STW is selected by drawing a sample from an exponential distribution function. This function is constructed based on the desired mean value.

This mean value is also called the split factor and is the average number of logtra on a supplied STW. It was found that the split factor depends on the number of supplied STW, since on the busier days, the clients tend to buy larger quantities. As amount of products on a supplied STW is constant the this effects the split factor. Equation 5.1 shows how the split factor is calculated in the model. As the sample from the distribution would be a 'double' (decimal number) it must be converted to an integer as it is only possible to place whole logtra on a STW. This is done by ceiling the number, rounding it to the higher number. This prevents a zero to be drawn from the distribution, but increases the mean with 0.5. This has been taken into account in equation 5.1 and the solution has been validated to give the desired results using a small scale experiment.

$$\text{Splitfactor} := \text{Nrof suppliedSTW} * 0.000115 + 4.1 \quad (5.1)$$

For STW with more then one logtra other attributes are now also determined using random distributions. These are listed in table 5.2 indicating the purpose of the distribution, and the values used. For more complex or detailed selections a table prescribing the options and cumulative chance per options is used in combination with a uniform distribution between 0 and 1.

#### Logtra Element

A Logtra element represents a single logtra. All data about its client and destination, as well as timestamps can be save to the logtra's attributes. These logtra can be added to the freightset Queue of a supply STW or buyer STW.

#### Create Supply STW Element

Each logtra required to fill a supply STW is created at the supply generator as well. The logtra has to contain information about its buyer, and where the buyers STW can be found in the

Table 5.2: Variable attributes of a supply STW, and distribution used to determined these

Variable	Used to Determine	Distribution Type	Mean	SD	
Split factor	Nr of logtra per STW	Exponential	Split(#STW)		
BufferInTime	Time between STW entering buffer	Normal	1880	500	
StorageTime	Determine place in storage	Normal	900	450	
			<b>Start</b>	<b>End</b>	<b>Decision value</b>
Restkoop	Last logtra on STW is drop off: y/n	Uniform	0	1	0,656
Sortingcolor	Determine STW color	Uniform	0	1	0,832
BufferNr	Select buffer for STW	Uniform	0	1	Table

process. The client information also includes the buyers category, determining the time path for the logtra.

To ensure realistic clients when it comes to purchasing behavior and placement in the distribution area an elaborate client data table was constructed, based on the real client data. First of all the clients are labeled either 'fixed' when they have one or multiple fixed positions assigned in the distribution area, or 'free' when they have not. The exact layout of the distribution area was loaded in the simulation, and in the client data table the locations of fixed clients were defined as well.

Next, each client's purchasing behavior per hour of auction was included. This was required since this differed vastly. For example several buyers normally only started to buy products after two hours into the auction. These fluctuations arise from the fact that certain buyers focus on specific product groups that are auctioned at specific moments during the day. This has a large effect on the congestion in the distribution area later on, and therefore had to be taken into account.

It was also taken into account that only about 15% of the 'free' clients did show up, therefore the client profile table is read from an external file at the start of the simulation, and per 'free' client it is determined whether they participate or not. This leads to a different client profile table for each simulation. To finish the table the chance per client is calculated based on each client's amount of purchases in the table. This is done again every hour, as these numbers change per hour.

Using a uniform distribution a client is selected for the logtra and the client's details are saved to the logtra. If the client does not have a fixed position in the distribution area it is also checked whether it has been assigned a position for this simulation already. This is done based on its documented preferred path close to its final destination. If this path, and the neighboring paths do not have a space the client is placed in an overflow path.

Besides the client data, the logtra also receives a timestamp for the time of auction, and some more determining its planned time path. Now the logtra is added to the freight set of the STW and it can start its journey.

The STW is entered in the main process by adding it to the storage. Using the Storage time distribution the STW is assigned a place in the storage queue, in order to recreate the shuffled supply of STW from storage to the buffers.

### 5.4.2. Buffer Manager Element

The buffer manager elements control the flow to supply STW from storage to the buffer, based on the actual process. In the simulation this step is relevant as the order in which STW leave the buffer is determined. As the distributor's selection of a STW from buffer was found to be unpredictable it was chosen to shuffle the STW at this step based on the dispersion in time STW are recorded to be in the buffer. The moment the STW enters the buffer also the time stamp BuffIn is made on the STW, and on all its logtra.

### Distributor Element

Each distributor working in the process is represented by a distributor element. This element runs a process that picks supply STW from a buffer, determines the route to drive to deliver the logtra on the STW, and delivers the logtra in that order. The drive times, and handling times are simulated as hold times in the process based on random distribution and a drive time table as will be discussed on the next section.

#### Select Next Task

First a distributor will find itself a new task in the form of a supply STW with logtra. To do this it will drive to the nearest buffer side, which is determined based on its current location. A buffer is selected from the ones at this side using a uniform distribution, spreading the distributors over the buffer equally. However, it is checked if the STW in one are far behind on the other buffers and the choice can be adjusted accordingly, similar to the real operation.

Currently the distributor seems not to use the light indication system consistently causing a random flow of STW leaving the buffer. This is recreated as the STW are already in the buffer in this order. The Distributor can therefore select the first one in the queue of its color. If the distributor is orange but the orange queue is empty it will take the first STW from the green queue.

#### Determine Route

Not that the distributor has an STW it determines the route. This is done using the nearest neighbor principle using the drive time table. The logtra are rearranged into the freight set of the STW in the order of the determined route. The distributor processes the first, delivers it, and again takes the first from the set to process.

#### Drive Time

The drive times between all locations in the distribution area are measured and provided by Royal FloraHolland. A drive time matrix is created from this, of which the column numbers and row numbers represent locations 0 to 51. In this 0 is buffer side AB and 51 is buffer side EF. The remainder of the numbers represent the paths 1 to 50. The drive time is simulated as a hold time in the model. After this time the distributor's former destination becomes the distributor's location or origin.

### 5.4.3. Wait Queue Element

A Wait queue element is a passive element that houses a TomasQueue in which distributors can wait until their destination is available. A wait queue element can be assigned to a single destination, (path position) or to multiple as is currently the case in the real time operation.

#### 5.4.4. Path Position Element

Path positions are the possible destination for logtra located in the paths of the distribution area. This path position owns a buyer STW on which logtra for the same client are accumulated. It also is assigned to a specific wait queue element. The path position is activated when a distributor enters its wait queue and the process of handling the distributor and receiving the logtra is started. This includes a duration time based on a random distribution which allows the path position to be occupied and a waiting line to be filled with other distributors.

To determine the handling time for a distributor a sample was drawn from a normal distribution. This distribution is based on data measured manually by several distributors. The measurements were done while observing the process, using a stopwatch. The time measured included only active order handling time; waiting time was excluded from the measurements to allow the impact of future state scenarios on the waiting time to be measured in the model. The mean found was 55 seconds, and the standard deviation 15 seconds.

The path position is also capable of forwarding a filled buyer STW. To do so a new buyer STW is created, and the old one is destroyed. All data of the logtra on the old buyer STW is documented in this process as well, and the created buyer STW are counted.

##### Buyer STW Element

The buyer STW is basically the same as the supplied STW. However, a separate element definition was created to prevent the mixup of these two in the simulation. It is desired to count both the supplied STW to ensure the right amount is created as supply, and the buyer STW to be able to measure the amount of buyer STW created in the process.

##### Create Buyer STW Element

The path position creates a new buyer STW element when the current one is forwarded. This one looks similar to the supply STW, but some attributes are different. It owns a freight set to accumulate logtra, and several timestamps can be added to the STW as well. In the same sequence the previous STW is processed, sending all the data from the logtra and STW to the relevant instances. Logtra are placed in specific queue from the GUI output updater as well, to allow processing of data like the median and percentiles.

#### 5.4.5. Path Manager Element

The path manager element is introduced to monitor the time path of the logtra on the buyer STW in its path. When a logtra that is overtime is detected the path position is triggered to change the buyer STW. As in the real process this does happen based on manual observation this is not always detected on time, so a chance of on time detection is used in this process.

#### 5.4.6. GUI Output Updater

To process the data created and display progress of the operation on the user interface (GUI) another element is used. This element does not interfere with the operation, but every simulated 15 minutes it updates the data on the interface and constructs logfile data lines. When the simulation is finished all data will be written to separate files that allow the accumulation of data in a structured manner, and simple processing of this data later on.

##### Output Documentation

Several output files are created in the form of comma-separated text files, as listed in table 5.3. In each file a single row represents a single run, except for the logtra log file. As

Table 5.3: Automated output files

Output File
Seed nrs
KPI
Lead times
On time
DLT Dispersion
Logtra log (optional)

each row in constructed the same way all data can quickly and simply be processed using excel for example. The initial seed number of each run, which determines all the other seed numbers used, is documented making recreation of experiments condition and debugging possible. Many performance indicators are documented in the KPI file, and more detailed process overviews are documented in the remaining files. The logtra log file is optional to construct as this consumes a lot of computational power, lengthening the simulation time by a factor 10. In this file all data per logtra is logged, from the distributor handling it, to the buyer STW is was delivered on.

The remaining three files all consist of data points for every 15 minutes of operation, representing the cycle time per step, the lead time dispersion in five percentiles and the on time performance development per 15 minutes for both Buf and Wis.

## 5.5. Verification

Verification of the model is required to ensure the model is coded correctly. In the previous section the model structure and inputs are specified. During the verification it is assessed if the model as specified was implemented and encoded correctly. To do this the following aspects have been focused on during verification.

- Is the input data correctly loaded?
- Is the prescribed behavior of the elements encoded correctly?
- Are the output values calculated correctly?

Is the input data correctly loaded?

The model uses several input files that prescribe the distribution environment in detail, to ensure it resembles the actual layout and setup of the process at Royal FloraHolland. The input files are created in *Microsoft Excel* and transferred to comma separated textfiles. The text file is loaded and read line by line. Depending on the purpose of the file, each line is written to a array or table (2d array) in the model like with the drive time table, or per line a required element with specific characteristics is created like with the path positions.

To verify these processes perform correctly a small test was created where the load procedure was initiated using a button in the GUI, and it would return specific values from the table, or the created table would be displayed in the GUI. Using this technique it was found that all input data from text files is loaded and used correctly in the model.

Is the prescribed behavior of the elements encoded correctly?

Both the processes of created elements as well as interaction between the elements are assessed while verifying the model. The main approach to achieve this was to use step trace in

Table 5.4: Input data of created test cases

	<b>Top line</b>	<b>Base line</b>	<b>Bottom line</b>
<b>Average supplied STW</b>	8643	6714	4205
<b>Average number of distributors used</b>	268	247	214

small zone tests. Specific conditions were created to verify correct behavior of the involved elements. Step trace provides an overview of the events on a time line. For more detailed insight in the process steps debugging step tracing was used, making it possible to look in-sight the process tracing the events through the code.

Additionally a logtra log was created, writing a line with all data from a logtra that passes a certain point in the code. This data includes details of the elements the logtra has interacted with, and time stamps of most happenings. This logtra log was also used as a balance sheet, tracing all logtra in and out of the model, to verify no elements or data would disappear in the process.

Also animation was added to the GUI as this also helped to verify events taking place. The layout of the distribution area with all the active positions was created, and using changing colors per position the events taking place could be observed. In a small scale experiment with only one distributor active its movements could be traced using this technique as well.

Are the output values calculated correctly?

It is essential to verify the output calculations and this was mostly done by manually checking the calculations using the logtra log file. The correct functioning of this file was verified using step trace. With the raw data included in the file the outputs generated were correct.

## 5.6. Validation

The model is designed to resemble the flower distribution process at Royal FloraHolland Aalsmeer. The performance of the model is compared to the performance of the real process to validate the models accuracy. First a top line, base line, and bottom line have been constructed from the actual data of the operation. After this the model was run with the same amount STW and distributors as in these cases and the results where compared.

### 5.6.1. Test Cases

A top line, base line, and bottom line case have be defined to test the models performance. Each case resembles realistic input for the operation, and the corresponding output data was gathered to allow comparison with the model's performance given the same inputs. The three cases are bases on data from the period of September 2016 until August 2017. A clear pattern can be seen in the amount of products to be processed per day of the week. Mondays are the busiest, Thursdays are the quietest days, and the rest lies in between. The cases are created accordingly, Mondays being top line, Thursdays being bottom line, and the rest being base line. Averages are taken, and the case inputs are shown in table 5.4.

The model will be validated on its performance in these three cases. Later the impact of the future state scenarios will be measured using these cases as well.

Table 5.5: Performance of the model compared to the top line case

<b>Top line</b>			
	<b>Data RFH</b>	<b>Model results</b>	<b>Model deviation</b>
<b>Inputs</b>			
Nr of STW	8643	8643	
Nr Of Distributors	268	268	
<b>KPI</b>			
On time Wis %	83,8%	86,6%	3,4%
Productivity (Trans vs Hr)	32,41	32,21	-0,6%
<b>Operational outputs</b>			
Split factor	5,60	5,61	0,3%
Expansion factor	1,83	1,91	4,4%
Duration Auction	4,87	5,01	3,0%
Duration Distribution	6,53	6,54	0,1%
Deployed Distribution hours	1485	1506,5	1,4%
Average lead time [hr]	1,44	1,49	3,2%
On Time Buf %	74,9%	72,5%	-3,3%
<b>Average absolute deviation</b>			<b>2,0%</b>

### 5.6.2. Validation results

For the validation of the model each case was ran hundred times. The outputs per case where gathered and combined to be able to compare it with the operational data from Royal FloraHolland. The results are presented and discussed in the following sections. First the general outputs and are presented, giving an overview of the models performance. Next more detailed results are discussed giving better in insight in the model's performance.

### 5.6.3. Performance Overview

In tables 5.5, 5.6, and 5.7 the average results from the validation runs are presented alongside the data from Royal FloraHolland for each case. Also the model's deviation is given per output as a percentage from the original value. The average deviation was calculated based on the individual absolute deviations to give a final figure describing the quality of the fit on the presented outputs.

The average deviation as presented lies within 1.1% and 3,4% for the three tested cases, indicating the model's performance resembles the real situation quite accurately. The largest deviation is found in the duration of the auction in the bottom line case, with 9,9%. The other deviations all stay within 5% of the case data.

The duration of the auction can be related to the auction speed. This was modeled with a curve fitting the patters found in the data, and scaled according the number of supplied STW. The larger deviation for the bottom line case might be caused by the breaks of the auctions. The moment of taking a break, or not taking a break at all is something that is not taken into account in the model as here a break is always taken on the same moment. This might cause the difference for the bottom line as during the real operation those breaks are regularly skipped ending the auction earlier.

The modeled auction speed slows down near the end, approaching a horizontal asymptote. therefore the number of transactions generated near the end is significantly smaller and this limits the impact of the longer duration on the further results. However, a small impact on the on time performance and lead time must be considered as the time path per logtra is determined by the moment of purchase.

Table 5.6: Performance of the model compared to the base line case

<b>Base line</b>			
	<b>Data RFH</b>	<b>Model results</b>	<b>Model deviation</b>
<b>Inputs</b>			
Nr of STW	6714	6714	
Nr Of Distributors	247	247	
<b>KPI</b>			
On time Wis %	91,5%	92,9%	1,6%
Productivity Trans vs Hr	32,30	32,21	-0,3%
<b>Operational outputs</b>			
Split factor	5,36	5,39	0,6%
Expansion factor	1,82	1,78	-2,2%
Duration Auction	3,92	3,95	0,7%
Duration Distribution	5,41	5,38	-0,7%
Deployed Distribution hours	1108,5	1123,63	1,4%
Average Lead time [hr]	1,28	1,37	6,7%
On Time Buf %	85,0%	87,2%	2,6%
<b>Average absolute deviation</b>			<b>1,1%</b>

Table 5.7: Performance of the model compared to the bottom line case

<b>Bottom line</b>			
	<b>Data RFH</b>	<b>Model results</b>	<b>Model deviation</b>
<b>Inputs</b>			
Nr of STW	4205	4205	
Nr Of Distributors	214	214	
<b>KPI</b>			
On time Wis %	93,0%	96,2%	3,4%
Productivity Trans vs Hr	31,80	32,72	2,9%
<b>Operational outputs</b>			
Split factor	5,08	5,10	0,3%
Expansion factor	1,77	1,68	-5,0%
Duration Auction	2,33	2,57	9,9%
Duration Distribution	3,81	3,80	-0,3%
Deployed Distribution hours	669,0	655,35	-2,0%
Average Lead time [hr]	1,25	1,22	-2,6%
On Time Buf %	96,6%	99,1%	2,6%
<b>Average absolute deviation</b>			<b>3,2%</b>

## Detailed Performance

The overall performance of the model seems to fit quite well with the real situation. To validate this in more detail the performance during the operation is also measured and compared in this section. To do this the following aspects will be discussed.

- Average number of logtra at delivery
- Lead time dispersion
- Average lead time

### Average Number of Logtra at Delivery

The average number of logtra at the time stamp Wis per 15 minutes in the operation is recorded, and compared to the data of Royal FloraHolland. This comparison is plotted per case in the figures 5.2, 5.3, and 5.4. Looking at figure 5.2 displaying the top line comparison it is observed that the model follows a similar pattern as the top line, although the model gives slightly higher values during the major part of the operation and ends earlier. The same is seen in figure 5.3 with the base line data. The difference can be explained in the fact that the top line and base line data contains the data of various different operations with all different input values, including busier days, or day with less distributors. This lowers the average logtra per 15 min and stretches the duration of the operation, without altering the total amount of logtra being processed. This is not seen as clearly in the bottom line data, although also this shows that logtra are detected at Wis at later times as well.

The overall pattern in the lines seems to be alike for the most part. The dips are the breaks taken by the distributors. In the model these are timed strictly, but in the real data this can differ a bit more as the workers stop for a break in a bit more gradual manner. Especially getting back to work after a break goes gradual as many for example want to finish their conversation or stop by the restroom. This explains the more spiky behavior in the model compared to the data from Royal FloraHolland.

All together the model shows that it resembles the top line, base line and bottom line cases adequately when it comes to the logtra registered at wis per 15 minutes.

### Lead Time Dispersion

Another aspect that has been used to get more insight in the model is the dispersion of the lead time data. To achieve this the three quartiles and the 5% and 95% percentile were calculated. It was chosen to exclude the last 5% of the data at either end of the spectrum as in the data from Royal FloraHolland this would regularly include extreme values, giving lead times of more than the operation time.

In figures 5.5, 5.6, and 5.7 box plots are given displaying the dispersion of the lead times of the tree cases and the models results. The models give quite accurate results for the top line and base line; the results for the bottom line case show a small deviation. The middle 50% of the data is spread over a wider range, starting lower. This will influence the on time performance of the model in the bottom line case a bit, and might explain the 3,4% deviation of the on-time Wis performance from the model. This difference has to be taken into account discussing the results from experiments with bottom line inputs.

### Average Lead Time

The average lead time is measured from the moment the transaction is made at the auction, until the goods are forwarded to delivery. The lead time has been measured every 15 minutes to create more detailed insight in the process behavior and performance. The results

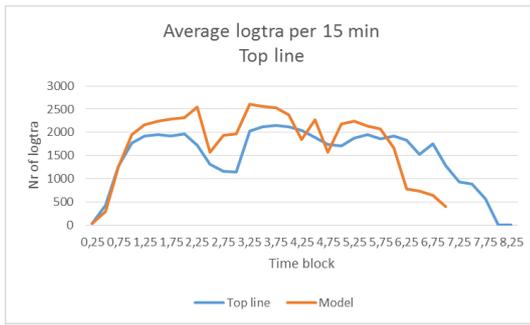


Figure 5.2: Number of logtra at Wis; Top line vs model

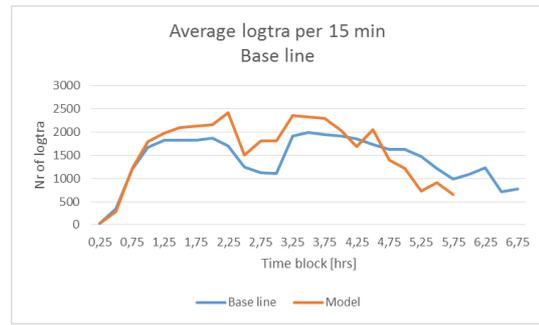


Figure 5.3: Number of logtra at Wis; Base line vs model

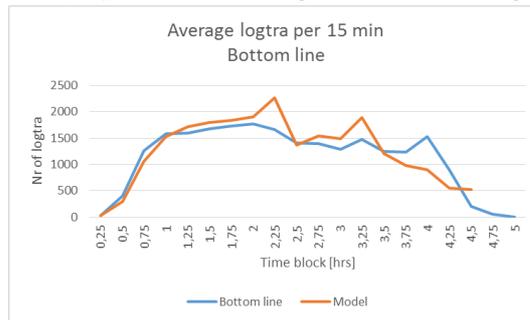


Figure 5.4: Number of logtra at Wis; Bottom line vs model

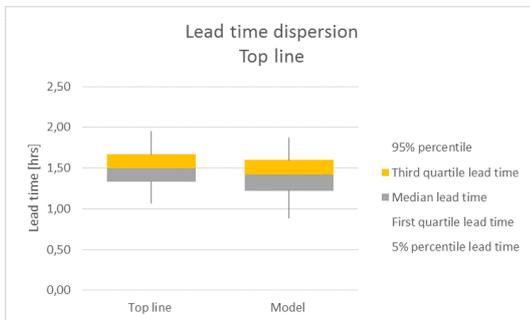


Figure 5.5: Dispersion lead time; Top line vs model

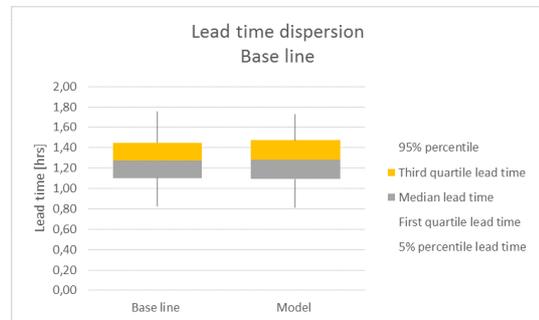


Figure 5.6: Dispersion of lead time; Base line vs model

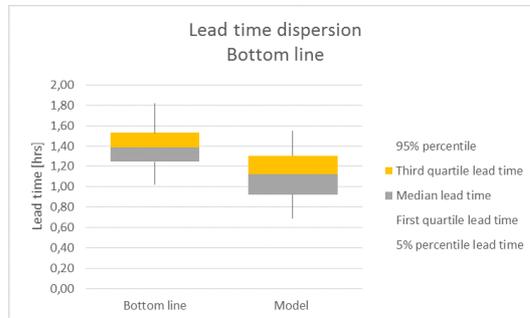


Figure 5.7: Dispersion of lead time ; Bottom line vs model

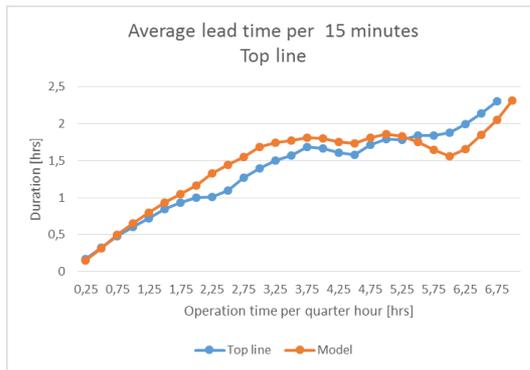


Figure 5.8: Average lead time; Top line vs model

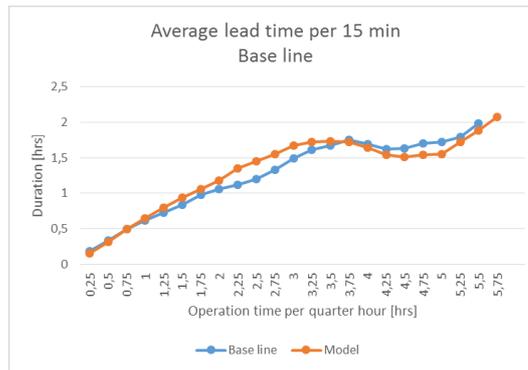


Figure 5.9: Average lead time; Base line vs model

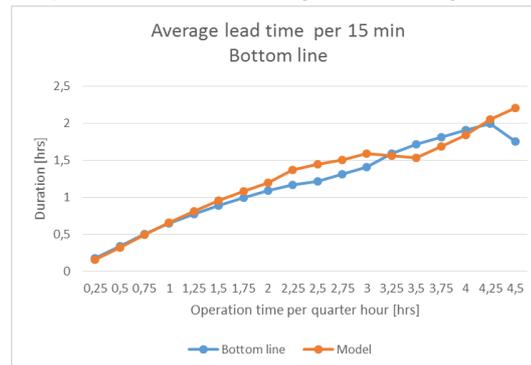


Figure 5.10: Average lead time; Bottom line vs model

are plotted together with the selected data for the top line (figure 5.8). The same comparisons are made for the base line and the bottom line as shown in figure 5.9 and figure 5.10.

Overall it can be seen that the model shows about the same average lead time in all three cases, indicating the model resembles the process behavior concerning lead time well. Near the end of the operation some differences can be observed. Looking at figure 5.10 the bottom line shows a more stable lead time near the end, while the average lead time in the model climbs a bit further. This could have to do with the model forwarding buyer STW only on strict criteria, while in the real situation the path manager can start early with forwarding the buyer STW when they are reaching the end of the operation. This could result in a slightly shorter lead time around this time.

An other striking difference is seen between the top line (figure 5.8) data and the model's results. The model shows a short dip in the lead time near the end, while the top line data only shows the lead time to stabilize for a short time before continuing upward. It is uncertain what could cause this.

## 5.7. Synopsis

In this chapter the design, structure, verification of the implementation, and the validation of the simulation model have been discussed. A higher level of detail than expected was required to model the situation at Royal FloraHolland realistically. This is partially caused by the fluctuating behavior of the trade and the human factor. However, the model created has shown the produce realistic results in all three of the creates test cases. Therefore the model is found suitable to test future state scenarios with.



# III

Design & Evaluate



# 6

## Future State Design

In this chapter the re-design of the current state will be discussed. First an ideal state will be drawn up, using the theoretical knowledge gained from the literature research. Based on this ideal state and with the distribution process in mind some future state scenario's will be developed.

### 6.1. Ideal State

A simple ideal state has been drawn up, based on the theory. In any order picking process the added value to the product is often seen as the service of gathering items in the order and delivering it to the client. The value is in delivering the client *what he wants, when he wants it*. This is what the ideal state focuses on. To achieve this the steps are planned backwards from the moment of delivery, using the expected step times. The planning also includes the number of workers required to achieve the goal.

Figure 6.1 represents how an order is fulfilled in the described ideal state. In this case it is assumed that the products are available and can be retrieved when desired. A client places an order for two products, including the desired time to receive it. A planning is made, determining the start times and the workers required. Two order pickers, starting at different times, are given the assignment to get a specific product and bring it to a specific location. Here the products arrive at the same time and are combined in a shipment. Then the shipment leaves and the products are delivered in time to the client.

This ideal state depicts a high level of service towards the client, as he receives what he wants, when he wants it. This example is over simplified, and does not take into account limitations of the current supply chain, or costs of such an operation, but it does provide an

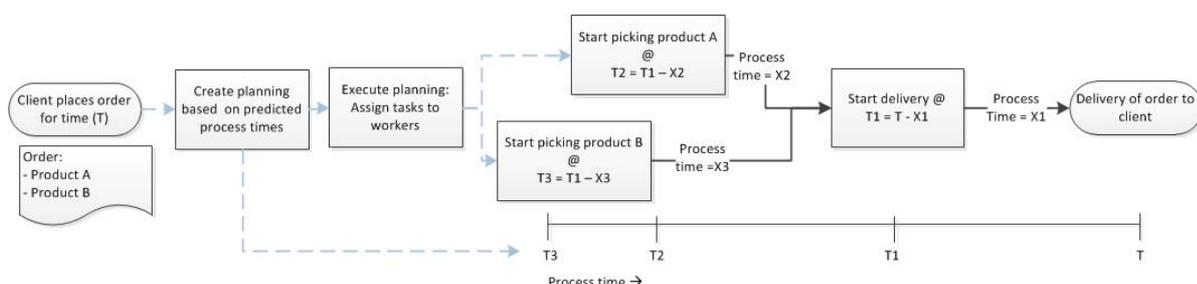


Figure 6.1: Ideal state

overview of the desired level of client service, and shows what information could be used to plan for perfect on-time delivery.

The ideal state will be taken into consideration while designing the future states for the process at Royal FloraHolland, keeping in mind restrictions of the supply chain and current situation.

## 6.2. Future State Design

Using the ideal state, the findings from the current state analysis, and the theoretical knowledge several future state scenarios have been developed. In this section the proposed future states and their desired effects are discussed.

Three future state scenarios have been developed, focusing on the planning of the operation. To enable the use of detailed planning and to prevent further congestion of distributors in the distribution paths also two active controls have been suggested. These controls are designed to improve effectiveness of the operation, and are essential in enabling the use of planning in the operation. All the following scenarios are made with improved control.

- Scenario 1: Current State Planning
- Scenario 2: Norm Time Planning
- Scenario 3: Client Demand Planning

The first scenario addresses some of the wastes found in the process, focusing on improving the execution of the current state. The second scenario takes it a bit further by adjusting the planning used. For this scenario it is chosen to stay within the boundaries of the current organization of the auction process and the distribution taking place at the same time, and the throughput time criterion. For the third scenario these boundaries are given up and the possibilities created by knowing the workload prior to the operation are explored.

## 6.3. Improved Control Design

Before these future state scenarios will be discussed in more detail, the design and purpose of the improved controls will be discussed. This control creates the foundation for the future state scenarios. The improved control consists of two aspects being:

- Task assignment control
- Dynamic path position control

These two controls are designed to improve process performance by minimizing some of the wastes, but more importantly to create conditions in which a planning can be used and executed properly. Task assignment control seeks to improve the on-time performance by doing tasks in the planned order as much as possible. Dynamic path position control seeks to create a more constant process flow by minimizing the hold up due to congestion in the paths.

First these two proposed parts of the improved control are presented, after which these controls will be tested to verify their individual effect on the performance. This is done to test whether each control has a positive effect. Based on these tests the controls will be combined into the improved control that will be applied in all scenarios as described above.

### 6.3.1. Task Assignment Control

The ideal state shows the creation of a detailed planning, and the ability to instruct workers with specific tasks to execute. Task assignment control is necessary if a planning is to be followed. Currently the automated buffer sorting process does not take into account the time path of the STW while sorting them. Also the distributors get limited information about what task to perform next when finished with the previous task, and regularly this information is ignored as well. These two problems will be addressed by the *Task Assignment Control*.

In the swim lane on page 59 the different elements of the task assignment control have been included. The green steps indicate newly added steps or existing steps that have been altered for this control. The following steps or elements are involved in the task assignment control.

- Distribution planning
- Select buffer track (central control process)
- Task assignment controller
- Select buffer track (distributor process)

#### Distribution Planning

First a distribution planning is created at the central control. A time schedule for each logtra is already in place. To create the distribution planning the start time for a supply STW is determined by examining the load on the STW and selecting the logtra with the earliest start time. This start time is given to the STW as start time as well.

#### Select Buffer Track Procedure

Based on its start time a track is selected for the STW arriving in the buffer. The tracks will be filled with STW with increasing start times, to ensure that the first one in the track is always the one with the earliest start time. The place of all STW in the buffer is reported back to the Task assignment controller.

#### Task Assignment Controller

Two task assignment controllers are used, one at each buffer side. The controller knows for all buffers at its side which STW has the highest priority and what its location in the buffer is. The controller assigns each available distributor arriving at the buffer side to a specific buffer and a specific buffer track from which the distributor will then take the first STW, with the aim to process the STW with the earliest start times first.

#### Assign Task to Distributor

The selected buffer and buffer track are communicated through to the distributor using the Voice information system. The dialogue starts as the distributor announces that he arrived at the buffer side and the buffer number is returned. When arrived here the distributor notifies this, and the buffer track number is given. This distributor now takes the first STW in that track, and scans the bar code. This is registered at the task assignment control and the STW leaving the buffer is registered.

### Modeling Task Assignment Control

The functionality as discussed above has been modeled, to make it possible to measure its effects on the operation. The buffer sorting procedure has not been modeled in detail. The buffer has been modeled as a single queue per color category in which the STW are placed in the order required for the desired outflow of the STW. It is assumed that a control is able to sort the STW as desired, enabling the distributor to take the right STW from the buffer. This assumption is based on the fact that the buffers have at least 10 tracks for the sorting, and the STW are supplied in more or less the order of the auction which is close to the desired order.

The task assignment control's functionality in the model is reduced to the selection of a buffer at the buffer side as the tracks are not modeled individually. When a distributor arrives at a buffer side it gets assigned to a task. This STW will be marked as assigned until it is picked up, to ensure other distributors will not get assigned to the same task. This is seen as a short forecasting horizon for the controller.

### 6.3.2. Dynamic Path Position Control

In the ideal state scenario the two products arrive at the start of delivery at the same time. If this is achieved it could lead to congestion if at that location not enough space is available to transfer to products to the delivery medium. In the current state this is seen a lot, as multiple distributors have to deliver products to the same buyer STW. This leads to congestion in the paths and waiting times for the distributors. This has to be prevented in future states.

The dynamic path position control is a system of controllers within the same path that work together to minimize the waiting time for distributors. This is done by optimizing the use of space as path positions are no longer fixed to a single client during the entire operation, but can be changed to other clients depending on the number of transactions to be handled per client. In the swim lane on page 59 the added or altered steps for this control are indicated in red, and listed below.

- Assign buyer to path
- Dynamic client position control
- Provide path position nr of drop off

#### Assign Buyer to Path

To enable this functionality a client position controller is created for each active client. This is done as the client becomes active at the auction. In the current state the client would then get assigned to a path position, but in the new structure the client only is assigned to a path. This is registered in the client position controller as well.

The clients will be divided over the different paths using on the historical purchase behavior of the client. The average amount a client buys is registered to keep track of the potential workload in each path. It is aimed to spread the workload evenly, but also a constraint is applied to the number of clients per path. As there are 1122 positions that can be used, and a max of about 800 potential active clients each path can be filled with two less clients as it has positions. This ensures that a path never has more clients than positions, and has at least 2 positions that can be shared.

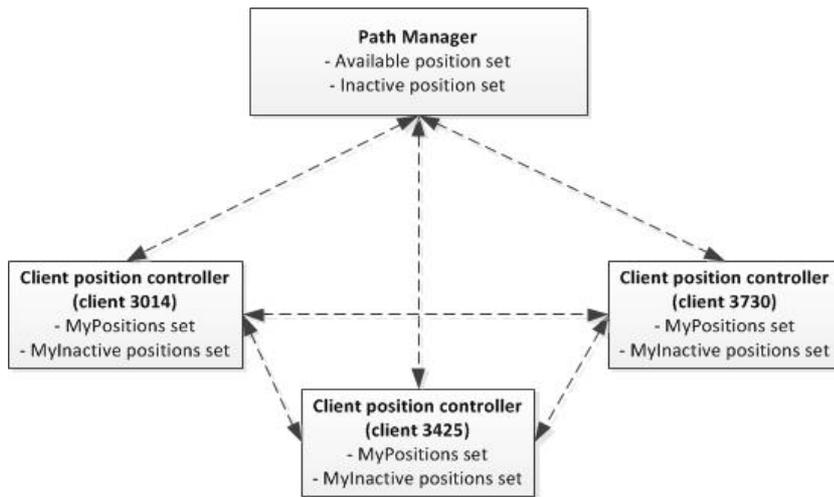


Figure 6.2: Control structure of three client position controllers in a path

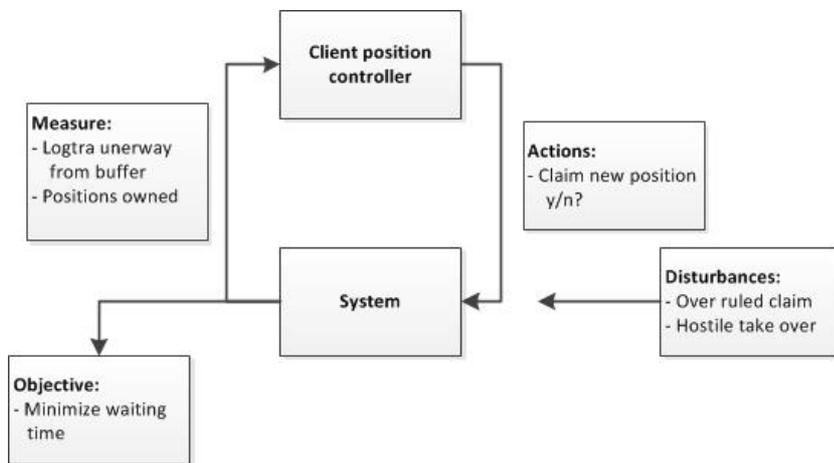


Figure 6.3: If-then-else strategy of client position controller

### Client Position Control

The dynamic client position control structure consists of multiple client position controllers. Each of these is fixed to a path, and within their path the controllers work together to minimize the waiting time for the distributors through optimizing the use of space in the path. The control is limited to the boundaries of a path and can therefore only locally optimize. The structure of how the individual controllers the path work together is given in figure 6.2. Each controller holds the positions it owns in a personal queue. Depending on the workload some of its positions can be marked as inactive by the controller, and this allows other to claim them. The Path Manager element is not actively involved in the process, but provides an overview of all available and inactive positions in the path. The individual controllers will use this to find new positions. In the case of a hostile take over the controllers will also communicate directly to find the best candidate position as will be explained later on.

The client positions controller is called upon every time a distributor arrives and requests a position to deliver the clients logtra. The controller then uses an if-then-else strategy to decide whether to take action or not. The control cycle is shown in figure 6.3. Each controller has the objective to minimize the waiting time and therefore aims to direct the distributor to the position with the shortest possible waiting queue.

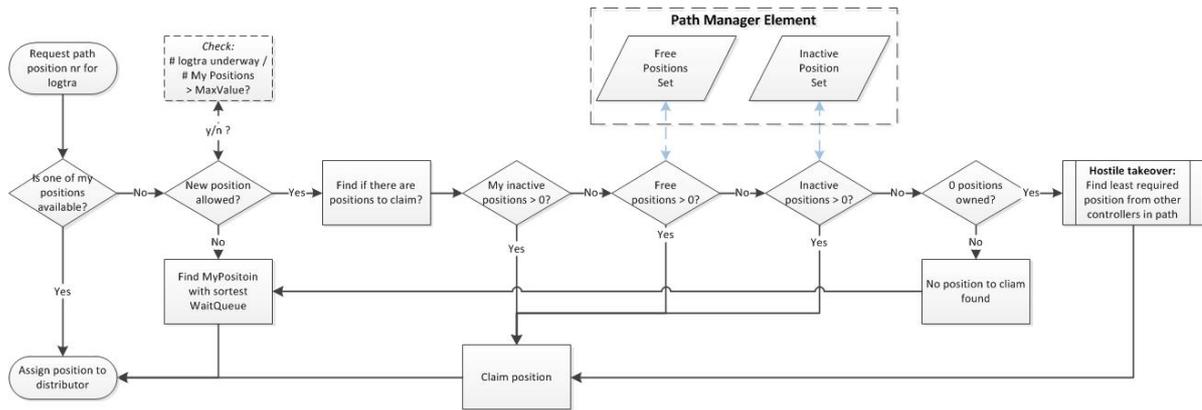


Figure 6.4: If-then-else process of controller

In figure 6.4 the used if-then-else strategy for the controller is displayed. If the controller does not have a position that is not occupied it will check if it is entitled to a new position. If so, it will look for this in several places, in a specific order. If no new position can be found through these channels it can use a hostile take over. This is only allowed if the controller would otherwise have no position at all.

The hostile takeover procedure will check all client position controllers that own more than 1 position, and selects the least busy position to claim. This position is then taken over and the distributor is added to the back of the line. If the position houses a buyer STW with products on it, the STW belongs to another client and must be changed first. This check is embedded in the current state process and therefore this will be taken care of automatically.

#### Instruct Distributor

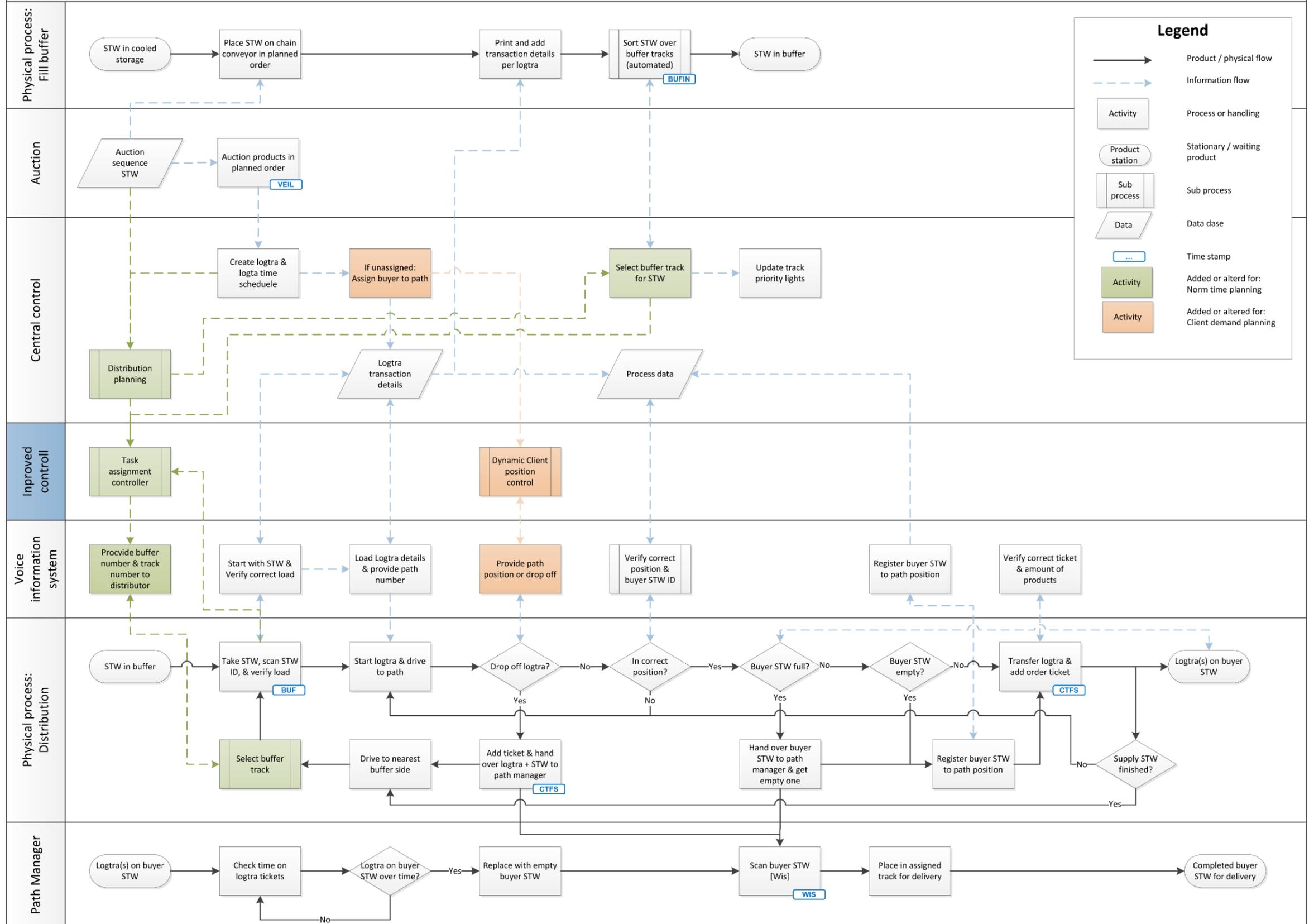
The selected position is communicated to the distributor via the voice information system. As the distributor reaches the right path it will notify this via the voice information system. At that moment the controller is activated and will return the selected position number. From here on the dialogue remains as before.

The controller as described was implemented in the model and the necessary communications were added. The functionality has been tested to verify its functioning and it was found to perform as desired.

These controls will be tested individually. In chapter 7 the results from these tests will be given and discussed.

Order handling process flows – Improved control

Phase



## 6.4. Scenario 1: Current State Planning

In the first scenario, current state planning with improved control, both controls as proposed above are implemented. The planning used for the operation is not changed from the current state. This means that the time path for the logtra is kept the same, and also the desired order of execution is not altered. However, the proposed controls are implemented together.

The planning used in the current state is based on a predefined time path for each logtra, based on the moment of purchase at the auction and the buyers preference. From the buyers 90% have agreed to receive the transactions within at most 2,5 hours measured from the moment of purchase, the remainder of the buyers has agreed to a 4,5 hours maximum delivery time. To achieve it is stated that the logtra must have started distribution within 1,5 hours. The moment the logtra has to be forwarded to the delivery is respectively two hours, or four hours, depending on the buyer. This time schedule will be applied, determining the start time for the STW.

The controls are discussed thoroughly in the previous sections. Implementing these together should not interfere with one another as the controls have impact on other parts of the operation, combining the positive effects of both controllers.

This scenario is included in the experiment as it will the impact better control in the form of target information provision, and dynamic use of information can have on the performance of the operation at Royal FloraHolland. It also functions as a second 0-state experiment that will provide insight in the effects of the planning strategies proposed in scenario 2 and 3. As all three scenarios use the same controls the effects on the planning strategies can be measured.

## 6.5. Scenario 2: Norm Time Planning

In the ideal state detailed planning is made, based on the time it takes to perform a handling or task. The current state however uses a standardized planning that does not take into account characteristics of the task assuming each step takes the same time. This will be changed in the second scenario, which is the norm time planning scenario.

The ideal state also shows products being picked on command. At Royal FloraHolland this is not preferred because of multiple factors. First of all the storage space is scarce and supply STW are therefore packed closely together. This makes it impossible in the current setup to collect a specific product without moving a lot of supplied STW around first, involving a lot of labor. Secondly, if this would be possible it would still be very costly as the facility is enormous and lots of drive time would be introduced. Batching of transactions is therefore a wise thing to do. Thirdly all products are processed the same day, emptying the entire storage every day.

However this has some disadvantages. The logtra on a STW with the earliest delivery time and the number of logtra on the STW together dictate the start time for STW. Luckily this difference is often small as the products on a STW are auction around the same time. Unfortunately it is inevitable that, if all is to be delivered in time, some logtra are delivered too early; especially when there are many logtra on a supply STW.

For the reasons as just mentioned also in the norm time planning scenario the logtra are processed with the STW they arrive on, just like in the current state. However, the start time of the STW is calculated based on the specification of the load on the STW. A norm time is calculated for each STW, and this is subtracted from the earliest time a logtra on the STW

Table 6.1: Comparison of planning methods

STW	Process time	Deal line STW	Current state		Norm time planning	
			Start time	Priority order	Start time	Priority order
1	0:05	10:03	9:33	1	9:58	2
2	0:05	10:04	9:34	2	9:59	3
3	0:05	10:05	9:35	3	10:00	4
4	0:05	10:06	9:36	4	10:01	5
5	0:05	10:07	9:37	5	10:02	6
6	0:05	10:08	9:38	6	10:03	7
7	0:05	10:09	9:39	7	10:04	8
8	0:35	10:10	9:40	8	9:35	1

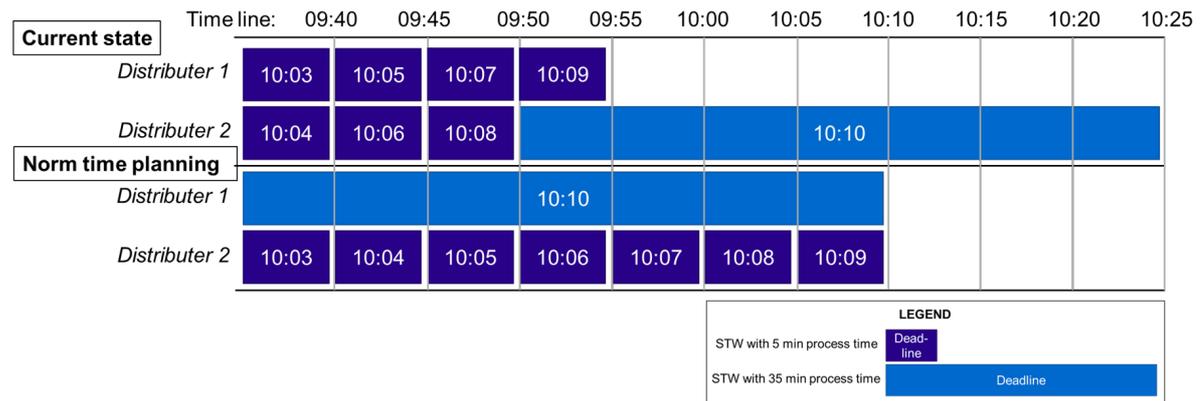


Figure 6.6: Different prioritizing methods compared

has to be at the next step in the process. This is used as the start time for the STW, which determines the priority between the STW in the buffer.

In table 6.1 an example is provided comparing the planning methods. As The last STW in the row will take 35 minutes to process. This is taken into account in the norm time planning, but the current planning gives a start time to this transactions that is inaccurate.

Figure 6.6 shows the same transactions with the same deadlines. Two distributors get only 35 minutes to process these STW. The STW are assigned to a distributor based on the priority order. The results is illustrated in the figure. Notice that the norm time planning can deal with the specific situation, assigning the STW in such way they all are finished before the deadline. The current state planning can not deal with the problem, and while one distributor finishes after 20 minutes already the other one ends up finishing the last STW well past the deadline. This illustrates the effect the norm time planning will have on the performance, increasing the on-time performance as STW are prioritized on the required process time.

## Implementing Norm Time Planning

The swim lane on page 68 displays the future states including the improved control (purple) and the norm time planning (green) and client demand planning (red). To realise norm time planning the following two steps are altered or added.

- Calculate norm time
- Distribution planning

Table 6.2: Constants to calculate the STW norm time

Variables	Singe buy	1 pty	2-3 pty	3>pty
Constant	0	0	31,52	193,87
Nr of logtra	46,12	57,63	54,88	49,22
Nr of units	0	124,8	97,96	100,63
Drop off y/n?	0	-9,03	10,77	19,67

### Calculate STW Norm Time

The norm time of an STW is calculated using several different factors. As not all these are modeled, the norm time calculation has been adjusted for the model. For example the number of product units on a SWT is used in the original norm time calculation, but since this is not modeled the average number of product units on a STW is used instead. In table 6.2 the variables and constants used are displayed. The number of different product types (pty) is used to select a columns. The variables for the STW are multiplied with the constant in the column and this is all added up. The drop off variable is either 1 or 0.

### Distribution Planning

The use of the distribution planning has already been introduced with the task assignment control. The same functionality will be used in the norm time planning scenario, however the planning has changed for the norm time planning. Based on the calculated norm time the start time for the STW is calculated. The task assignment uses this start time in its process.

The use of norm time planning has been modeled as described in the previous sections. Its functionalities have been verified to work correctly. The norm time is calculated correctly, and this results in the adjusted start time. As the start time of an STW is also used to measure whether is left the buffer on time the output will measure this performance based on the adjusted start time.

## 6.6. Scenario 3: Client Demand Planning

The third scenario is the client demand planning with improved control. The ideal state showed the delivery of the client order, at the time he wants it. Currently this is not incorporated in the throughput time criterion, as the moment of purchase is not chosen by the client, but does determine when the client will receive the product. In this scenario this will be changed. The client demand planning scenario is pull based, and aims to increase the service towards the client, while creating a more constant process flow.

For this scenario predefined time blocks are introduced in which clients can receive their goods. Each client is assigned to a time block so that all logtra for a client can be processed in the same time block. In this way the logtra for the client get bundled before delivery, while a client no longer needs to occupy a path position throughout most of the operation.

To achieve this setup several changes must be made. In the swim lane on page 68 the added and altered process steps are indicated in red. The improved control, but also the norm time planning will be used for this scenario. The added or altered step are listed below, including the involved norm time planning steps.

- Buyer time block schedule
- Auction
- Create logtra & logtra time schedule

- Calculate norm time
- STW in cooled storage
- Distributor planning
- Dynamic path position control

For the client demand planning it was chosen to spread the process of eight hours, divided in time blocks of one hour each. a duration of eight hours was chosen to lower workload per time block. This was required as there is a maximum amount of distributors that can be deployed. If this was to be exceeded it would not be possible to ensure on time delivery to the client. Also a lower amount of distributors working at the same time decreases the chance they interfere with each other. Blocks of one hour each was chosen to keep the presorting of logtra prior to the distribution process to a minimum.

To achieve the client demand planning in the distribution process several preparations have to be taken. Mainly some steps have to be taken to ensure the logtra are supplied to the distribution area per time block. This requires the logtra to be loaded on supply STW together with logtra belonging to the same time block. Although these steps lay outside the scope of this research this process has roughly been thought out. This is included in the following description, although not all described steps will be modeled. Figure 6.7 has been included to illustrate the steps in which the client demand planning is prepared. The steps in the figure take place prior to the distribution process itself.

#### Buyer Time Block Schedule

The buyers (clients) are assigned to a time block permanently as this allows them to adjust their planning to this. The time block for each client is selected in cooperation with the client. This schedule is fixed and is used in the process of creating the logtra details.

#### Auction

Although the auction process itself will not be changed, the moment it takes place is. The auction no longer takes place simultaneously with the distribution process. This is required because of two reasons. First of all, all logtra for a client must be known in order to bundle these logtra in the same delivery. Secondly the logtra must be presorted based on the time blocks to make it possible to supply them to the distribution area in that order.

#### Create Logtra & Logtra and Time Schedule

The grower has announced the shipment prior to the auction. Using the transactions from the auction, the shipment details, and the buyer time block schedule the logtra are defined. The logtra details and shipment details are combined into a plan describing the compositions of the supply STW loads.

#### Calculate STW Norm Time

With this information the STW norm time, and the STW Start time are calculated. Using the start time for the STW a storage plan is made.

Important to notice is that all STW including a drop off logtra receive a bit more attention. As the drop offs can only be done at one location in the path it is necessary to spread these out a bit more. This done to prevent all drop off logtra to be planned at the end of a time block as this would cause tremendous congestion.

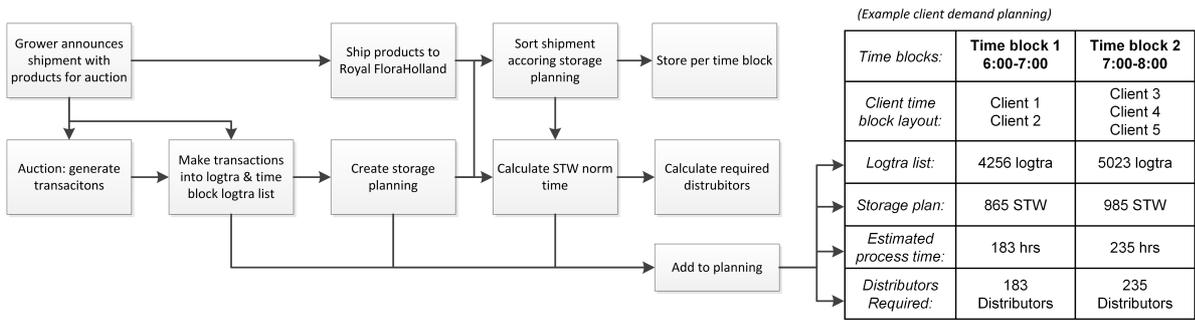


Figure 6.7: Preparation of the client demand planning

### STW in Cooled Storage

Between the auction and the distribution process the growers deliver their products. On arrival the products are split according the time block they belong to, based on the created plans. If necessary the products are divided over multiple STW. The sorted products are then digitally linked to their STW for the steps later in the process and to confirm the STW load composition. The STW is now stored at in the cooled storage areas, grouped per time block.

### Distributor Planning

Now that all details for the process are known a distributor planning can be made. By adding the norm time of each STW in a time block the required man hours is calculated, prescribing the number of distributors required per time block.

### Dynamic Path Position Control

Dynamic path position control plays an important role in this process. The bundling of the logtra per client causes more transactions for the same client to arrive in the path at the same time. On the other hand less clients are active in each path at the same time, making it possible to cope with the latter.

A small adjustment to the process must be made as it is important to spread the clients over the paths evenly per time block. This is done in the same way as was described before, with one more restriction keeping track of the workload per path per time block.

All these actions have prepared the distribution process to be executed per time block. The supply STW will be transported to the distribution area in more or less the desired order, automatically arranging them per time block. The task assignment control refines the sorting on start time in the buffer, and ensures that STW are processed in the right order. Dynamic path position control ensures congestion in the paths is limited, adjusting the positions layout according to the real time demand. All this together, the client demand planning and the improved control, ensure a better planned and controlled process.

### Implementing Client Demand Planning in the Model

To implement this in the model some changes have been made. First of all the entire auction is simulated at time step 0. First all logtra are created and sorted on time block. Secondly the logtra are placed on a supply STW, given a start time, and placed in storage. At the end of this the following is has been prepared for the distribution process:

- The distribution planning is made, giving each supply STW a start time
- Supply STW with logtra sit in storage, sorted on start time

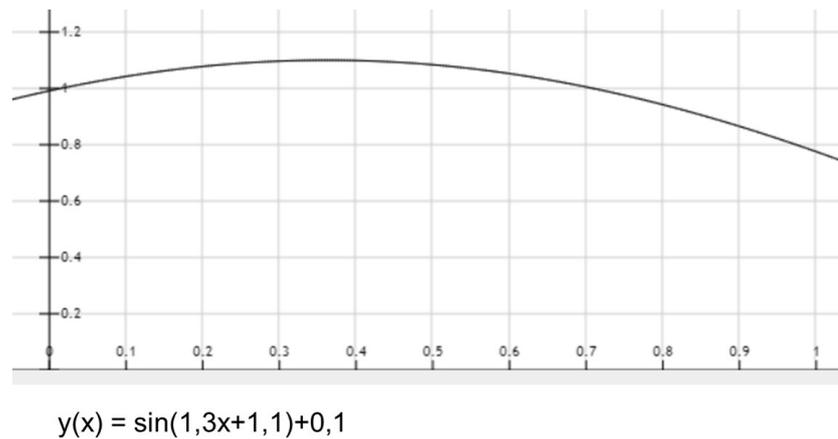


Figure 6.8: Client time block preference profile

- The number of distributors per time block has been calculated

The model uses a parametric setup for the client demand structure to allow for testing of different client demand planning settings. The number of time blocks and the duration of the time blocks can be given in via the interface prior to the simulation.

In the model clients are not fixed to a specific time block, but assigned to a time block at the start of a simulation run. This was done to create different spread of the demand per hour in order to see how the client demand planning deals with this. It is assumed that more clients prefer an early time block. The clients are assigned to a time block using a custom probability table. This table is constructed based on the number of time blocks given in, and the function  $y(x)$  between  $x=0$  and  $x=1$ , shown in figure 6.8. As each clients buys a different amount of products there will still clear fluctuation in the demand per time block.

To ensure the right number of distributors are activate each time block a "distributor planning element" is added to the model. This element is in charge of the distributor planning, and controls the number of distributors active at any time.

The rest of the process uses the same elements as before. Only the dynamic path position control uses one more restriction to spread the expected workload evenly over the paths.

### Outputs

For this scenario it was also required to adjust the used outputs to ensure the performance. The lead time can not be measured anymore as the auction takes place at some time prior to the process. Therefore the process time is measured, starting at the moment a STW leaves the buffer (Buf) until the logtra is forwarded to delivery (Wis). It was chosen to exclude the time in the buffer as this provides better insight in the effect of the scenarios on the process steps. After all, the time in the buffer is mainly influenced by the inventory kept in the buffer.

## 6.7. User Interface

The model is controlled from a user interface which is displayed in figure 6.10. The interface can be split in several parts. On the left the settings can be given in. Also a name can be give in under which the output files will be created. Next to this the an animation is presented, displaying the distribution area and depicting the occupancy of each path position. Next to the animation the KPI and other outputs are presented. Most are updated every simulated 15 minutes, others are only presented when the operation is finished. On the right top the

	Current state	Scenario 1	Scenario 2	Scenario 3
Throughput time criterion	✓	✓	✓	✗
Task assignment control	✗	✓	✓	✓
Dynamic path position control	✗	✓	✓	✓
Use of STW norm time	✗	✗	✓	✓
Disconnected auction & distribution	✗	✗	✗	✓
Delivery time blocks	✗	✗	✗	✓
Detailed distributor planning	✗	✗	✗	✓

Figure 6.9: Overview of functionalities of the current state and the future state scenarios

lead time is presented for every 15 minutes, consisting of the step times. At the right beneath this the on-time delivery and on-time start performance is plotted.

## 6.8. Synopsis

The following sub research question has been answered in this chapter:

- *How can information be used to influence the performance of the order handling process?*

In this chapter three future state scenarios have been introduced. Analysis of the current state have been combined with theory to create these scenarios. A simple ideal state scenario is used to illustrate the direction to take while redesigning the process to improve the performance and the service to the client. The three scenarios build towards this ideal scenario; a pull based operation. In figure 6.9 overview of the proposed future state scenarios is provided.

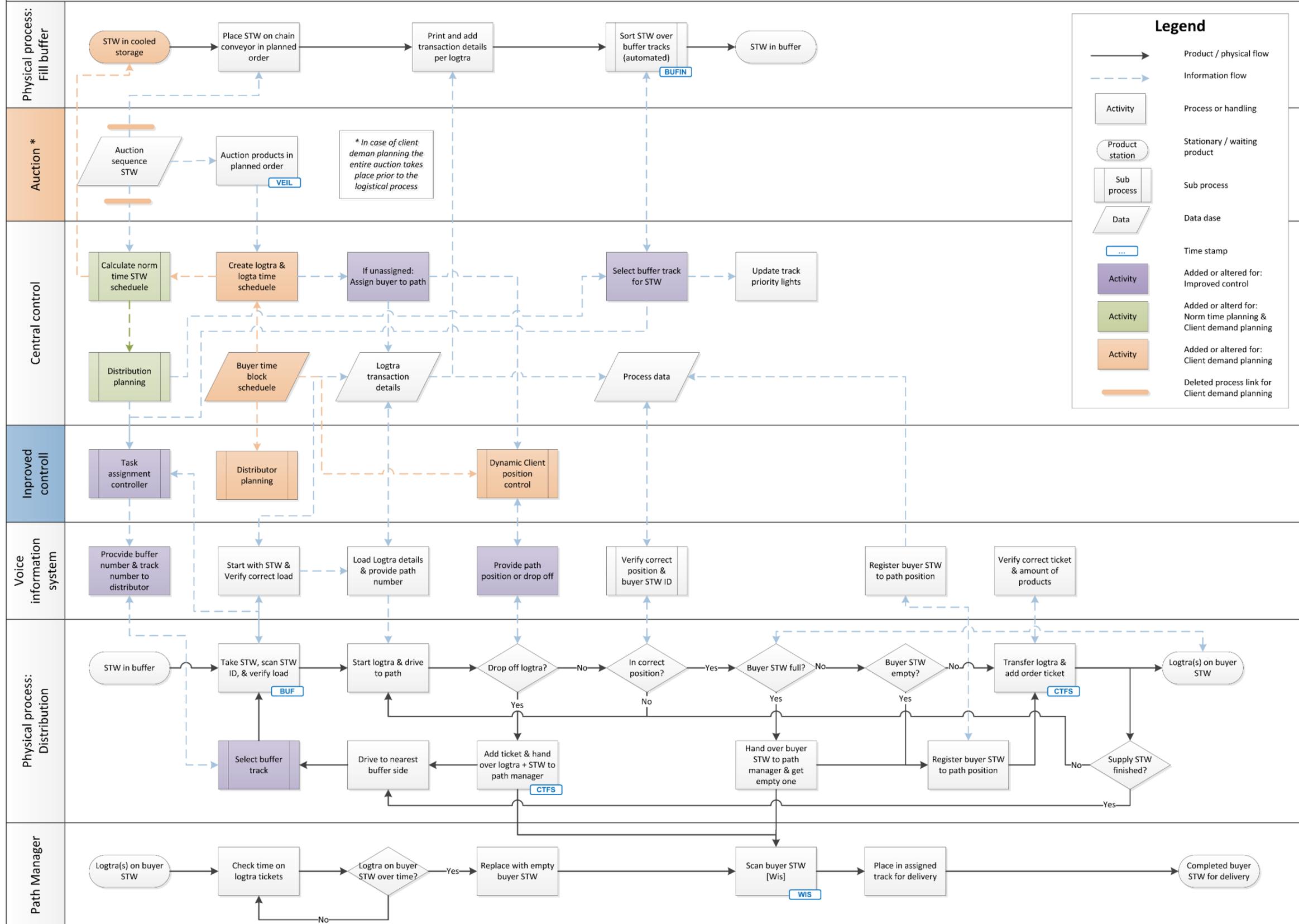
First the use of two controllers is proposed, aiming to take waste out of the process and improve performance through better coordination of the resources. These controllers also enable the effective use of other planning strategies, for which the final two scenarios are proposed. One of these operates within the boundaries imposed by the current throughput time criterion and the other scenario lets these boundaries go and aims to plan the operation based on the actual client demand.

These scenarios have been modeled and the functionalities have been verified using step trace and recreate desired scenarios to test specific functions. In the next chapter the experiment and the results will be discussed.



Order handling process flows – Norm time planning and Client demand planning

Phase



# 7

## Results

### 7.1. Experiment Setup

Using the previously described model the implemented controls and the proposed scenarios were tested and the results are compared against the current state model performance. Each experiment was repeated hundred times to create a solid set of data on the performance of the proposed scenarios. All different simulation runs are listed below.

- Current performance test
  - Current state (model)
- Control tests
  - Task assignment control
  - Dynamic path position control
- Future stare scenario tests
  - Scenario 1: Current state planning
  - Scenario 2: Norm time planning
  - Scenario 3: Client demand planning

First the two proposed controls were tested separately to be able to measure the effect of each control. The controls were tested in top line, base line, and bottom line conditions. These three tests cases have been discussed in chapter 5 and represent a busy day, an average day, and a quite day. The results are compared against the validated current state experiment results.

The three scenarios as discussed in chapter 6 were tested in the three test case conditions; top line, base line, and bottom line. The results of these experiments are evaluated and compared against each other and the validated current state experiment.

### 7.2. Controller Test Results

The results of both proposed controller tests are discussed in this section. The results of each test are compared to the current state model performance. First the task assignment controller's performance is discussed, followed by the dynamic path position controller.

### 7.2.1. Task Assignment Controller

The task assignment control aims to improve the on-time delivery performance by sorting and assigning tasks based on the desired start time. The KPI's of the proposed control are shown in table 7.1. The results are compared with the current state model performance.

Looking at the on-time delivery performance the task assignment shows an improvement in all test cases, although the improvement in the bottom line case is minimal. The effect of the control becomes more significant as the workload in the test case increases. This shows that when there are more logtra to process, it pays of more to control the execution order well. As more logtra have to be processed more would be delivered too late, making the impact of the controller more significant.

The development of the on-time delivery performance throughout the operation has been plotted in figure 7.1. Little difference is seen between the three test cases. Only the top line results are presented since here the trend is most noticeable. The results for both controls are given and compared to the current state model. A similar curve is seen looking at task assignment control and the current state, however, the task assignment control's on-time delivery performance decreases at a lower rate. This is in line with the expectations for this control.

No improvement of the productivity is seen in any of the test cases at all as was expected. The controller only changes the order in which the tasks are performed the productivity should not be effected.

The detailed outputs (table 7.1 only show significant improvements on the expansion factor and the on-time buf (start distribution) performance. Looking at the on-time buf performance a clear improvement is seen in the base line test. The bottom line test shows little improvement since the maximum (100%) has been reached. The top line case shows no significant improvement due to the backlog build up. At a certain point the backlog gets too large for the task assignment control to have a significant effect. The logtra picked from the buffer later in the process are so far over time, that processing them in the desired order has no effect on the on-time Buf anymore.

Task assignment control reduces the dispersion of the lead time. Figure 7.2 shows the dispersion of the lead time per test, with from left to right the current state model data and the task assignment test data for the bottom line case, base line case, and top line case.

The task assignment control also effects the expansion factor. As figure 7.2 shows the dispersion in the lead time is decreased. This reduces the expansion factor as logtra with the same time schedule arrive more often in the desired at the buyer STW. Therefore more logtra can be accumulated on the same buyer STW before one of these logtra reaches its change time, causing the whole buyer STW to be forwarded.

### 7.2.2. Dynamic Path Position Controller

The performance from the dynamic path position controller on on-time delivery and productivity are shown in table 7.2. The results are presented per test case and compared with the current state performance of the model.

The dynamic path position controller shows an improvement of the performance in all three cases. For the bottom line test an increase in the on-time delivery of only 0.4% is seen, while this is 1.4% for the base line and 4.7% for the top line test. About the same increase is seen in productivity. The control minimizes the waiting time for distributors, increasing the productivity and decreasing the lead time. This results in higher on-time delivery performance.

Table 7.1: Task assignment controller performance compared with current state performance

	Test case	Current state model	Task assignment control	Difference [%]
<b>KPI</b>				
On-time delivery (Wis)	Bottom line	96,2%	96,4%	0,3%
	Base line	92,9%	94,5%	1,7%
	Top line	86,6%	90,4%	4,4%
Productivity	Bottom line	32,7	32,8	0,1%
	Base line	32,2	32,2	0,0%
	Top line	32,2	32,2	0,0%
<b>Detailed outputs</b>				
Expansion factor	Bottom line	1,68	1,58	-6,2%
	Base line	1,78	1,68	-5,5%
	Top line	1,91	1,87	-2,6%
Duration Distribution [hr]	Bottom line	3,80	3,81	0,4%
	Base line	5,38	5,37	-0,2%
	Top line	6,54	6,54	0,0%
Total Distribution Time [hr]	Bottom line	655,3	654,3	-0,2%
	Base line	1123,6	1123,7	0,0%
	Top line	1506,5	1505,3	-0,1%
Average lead time [hr]	Bottom line	1,22	1,22	0,3%
	Base line	1,37	1,38	0,7%
	Top line	1,49	1,50	0,7%
On-Time Buf [%]	Bottom line	99,1%	100,0%	0,9%
	Base line	87,2%	89,8%	3,0%
	Top line	72,5%	72,6%	0,2%

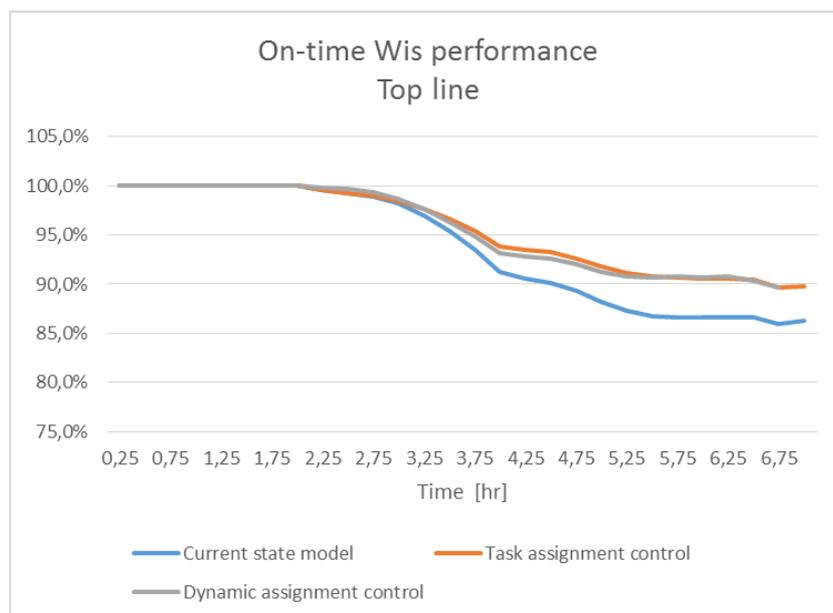


Figure 7.1: On-time Wis performance at top line test

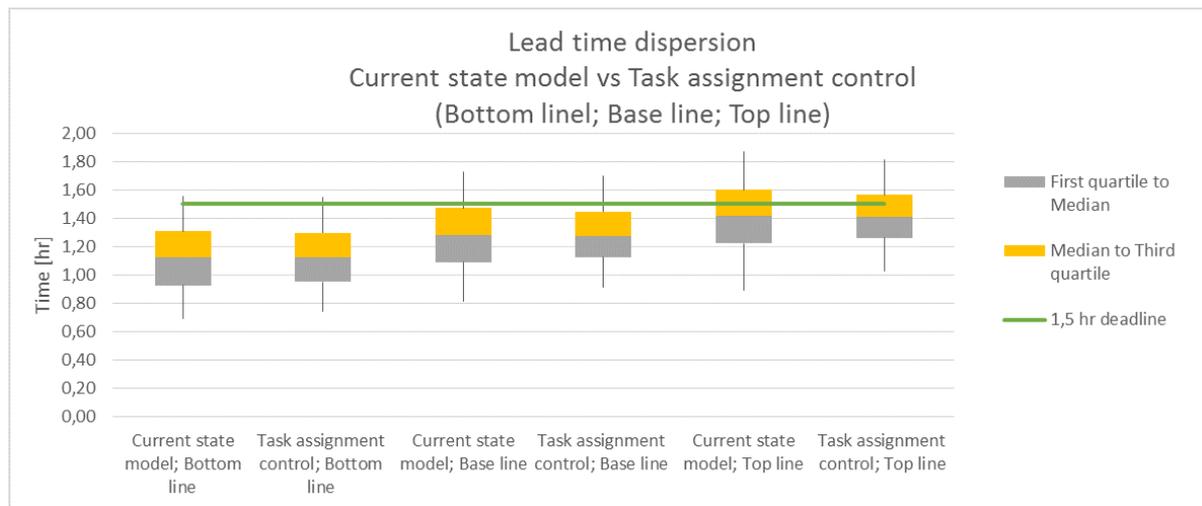


Figure 7.2: Lead time dispersion per test case; Current state model vs Task assignment control

The detailed outputs confirm this, as similar decreases are measured in the lead time, in the total distribution hours and in the duration of the process in each of the three test cases. This seems to originate from a reduction in waiting time for the distributors. The total distribution hours can be split over three categories: order handling time, drive time, and waiting time. When comparing the results from the control with the current state model it shows that the decrease in total distribution time solely comes from the decrease of waiting time. The waiting time is reduced with 8.7%, 21.4%, and 33.9% in the bottom, base, and top line case respectively.

The path position control allows positions to change 'owner' during the process, and clients can own multiple positions at any time. In the current state only between 83% and 86% of the available positions were used during the process. With the path position control this has been increased to over 99,7%. By using the space more efficiently the controller is able to minimize the waiting time.

The controller has a downside as the expansion factor increases tremendously. This increase is caused by two factors. First of all, the logtra can now be spread over multiple buyer STW, before this was restricted by only one or two buyer STW in most cases. Secondly, as the position may change owner before a buyer STW is filled to its maximum, more buyer STW are forwarded early. The control does not take into account the expansion factor in the decisions to change the positions owner. Also the present load on a waiting buyer STW is not taken into account when the controller selects a position for the arriving distributor. These effects are more evident in the test cases with less distributors are active at the same time. Therefore the negative effect on expansion factor is the largest in the bottom line case test and the smallest in the top line case test.

The controller also effects the time a logtra stays in the path. Figure 7.3 displays the increase or decrease of dynamic path position control performance compared to the current state model performance. Almost all steps show a decrease in step time, apart from the final step where the logtra waits in the path to be forwarded. This step represents about 30% of the average lead time and therefore has a negative impact on the average lead time.

Table 7.2: Dynamic path position controller performance compared with current state performance

	Test case	Current state model	Dynamic path position control	Difference [%]
<b>KPI</b>				
On-time delivery (Wis)	Bottom line	96,2%	96,6%	0,4%
	Base line	92,9%	94,2%	1,4%
	Top line	86,6%	90,7%	4,7%
Productivity	Bottom line	32,7	32,9	0,6%
	Base line	32,2	33,0	2,5%
	Top line	32,2	33,6	4,2%
<b>Detailed outputs</b>				
Expansion factor	Bottom line	1,68	1,94	15,2%
	Base line	1,78	1,96	10,0%
	Top line	1,91	2,07	7,9%
Duration Distribution [hr]	Bottom line	3,80	3,79	-0,3%
	Base line	5,38	5,29	-1,6%
	Top line	6,54	6,28	-4,0%
Total Distribution Time [hr]	Bottom line	655,3	651,1	-0,7%
	Base line	1123,6	1096,3	-2,4%
	Top line	1506,5	1445,9	-4,0%
Average lead time [hr]	Bottom line	1,22	1,22	0,2%
	Base line	1,37	1,34	-1,8%
	Top line	1,49	1,42	-4,7%
On Time Buf [%]	Bottom line	99,1%	99,3%	0,2%
	Base line	87,2%	89,7%	2,9%
	Top line	72,5%	80,0%	10,4%

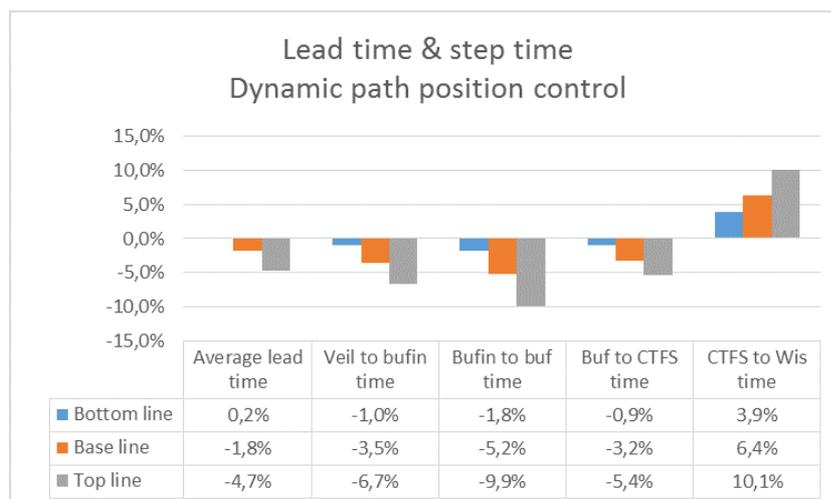


Figure 7.3: Effect of dynamic path position control on lead time and step times

### 7.2.3. Improved Control

Two controls are proposed and tested and both have shown to improve the KPIs of the operation positively. First of all the task assignment control minimizes the dispersion of the logtra, creating more constant flow in the process. The dynamic path position controls minimizes waiting time leading to an increase in both productivity and on-time delivery. Both controls influence a different part of the process therefore it is not expected to see interference between the two. Therefore both are found fit to use in the future state scenarios.

The improved control consists of the task assignment control and the dynamic path position control. This control will be used in all three scenarios that are tested next.

## 7.3. Scenario 1: Current State Planning

In the first scenario the improved control is used, but the planning is not changed. Testing this scenario will show the effect of the combined controls on the current state. This scenario is used to enable a proper evaluation of the other two planning strategies since all will use the same improved controls.

The performance of the first scenario is given in table 7.3. This shows significant improvement in both the on-time delivery and productivity compared to the current state model. The performance is most increased in the top line test case, while for the bottom line test case the improvement is only small.

The on-time delivery performance has increase with 0.6% in the bottom line case up to 8.3% in the top line case. The combination of the two controllers has a positive effect on the performance, increasing the on-time delivery performance to a higher level. The productivity has also increased, although, slightly less then the dynamic path position control achieved working individually. Nevertheless, in the more busy test cases the improvement in productivity is still significant.

In table 7.3 more detailed outputs are given. First of all in increase in the expansion factor has been observed as this has been increased. Again, most increase is seen in the bottom line test. The dynamic path position control test also showed a large increase in the expansion factor while this decreased with task assignment control. Combined the expansion factor becomes more constant at around 1.95. On the quite days the effect of the dynamic path position control seems to be more evident, while as the workload and active distributors increase this negative effect fades and the task assignment control improves it again, to within only 1.7% of the current state model value.

The duration of the distribution and the total distribution time shows the same improvements for the three test cases. As the dynamic path position control still successfully decreases the waiting time this is also seen in the duration and in the distribution hours. Because these are related to the productivity similar improvements are seen here as well.

The average lead time gives a less consistent result. In the bottom line test a small increase was recorded, but this changes to a small decrease in the busier test cases. Figure 7.4 shows the difference in step time between scenario 1 and the current state model. The time a logtra spends in the buffer or with the distributor are barely changed, however the time the logtra spends in the path and the time it spends in storage are effected. First of all the time the logtra spends in the path increases due to the use of more positions. a gradual increase is also seen between the different test cases. secondly the time in storage decreases. As the process is finished earlier the due to the higher productivity the backlog builds up less, shortening the average time in storage. The impact of this is little in the bottom line test case, but becomes lots bigger in the busier cases. The sum of these steps results in the average

Table 7.3: KPI's and outputs for scenario 1: Current state planning with improved controls

	Test case	Current state model	Current state planning + controls	Difference [%]
<b>KPI</b>				
On-time delivery (Wis)	Bottom line	96,2%	96,7%	0,6%
	Base line	92,9%	95,3%	2,5%
	Top line	86,6%	93,9%	8,3%
Productivity	Bottom line	32,72	32,91	,6%
	Base line	32,21	33,03	2,5%
	Top line	32,21	33,54	4,1%
<b>Detailed outputs</b>				
Expansion factor	Bottom line	1,68	1,93	14,6%
	Base line	1,78	1,91	7,4%
	Top line	1,91	1,95	1,7%
Duration Distribution	Bottom line	3,80	3,79	-0,3%
	Base line	5,38	5,28	-1,7%
	Top line	6,54	6,27	-4,1%
Total Distribution Time [hr]	Bottom line	655,3	651,3	-0,6%
	Base line	1123,6	1096,1	-2,5%
	Top line	1506,5	1445,9	-4,0%
Average lead time [hr]	Bottom line	1,22	1,23	0,9%
	Base line	1,37	1,36	-0,9%
	Top line	1,49	1,44	-3,5%
On Time Buf %	Bottom line	99,1%	100,0%	0,9%
	Base line	87,2%	92,9%	6,5%
	Top line	72,5%	86,7%	19,7%

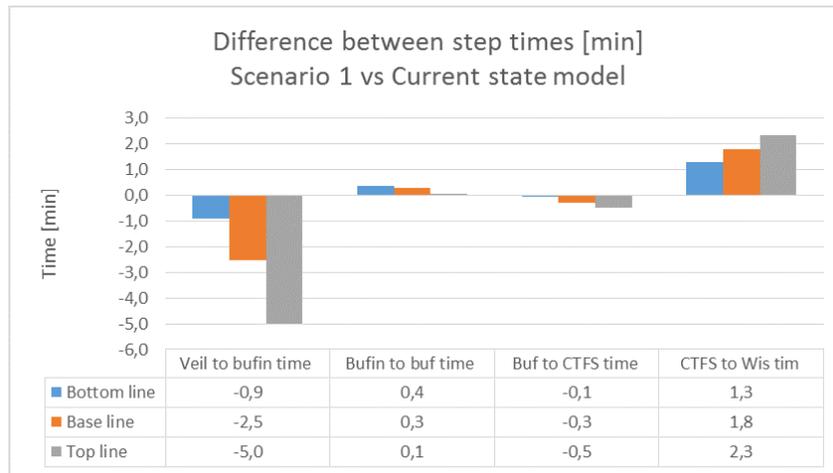


Figure 7.4: Difference in step time of scenario 1 compared to the current state model

lead time as seen in table 7.3.

The distributors productivity goes up but the effect of this on the average lead time is minimized by the forwarding procedure which takes more time due to the dynamic path position control. Despite this, scenario one shows to improve the performance looking at the on-time delivery and the productivity.

## 7.4. Scenario 2: Norm Time Planning

In the second scenario a norm time planning is introduced. By planning the process order based on a more accurate estimation of each task's duration it is thought it will increase the on-time delivery.

The on-time Buf percentage is based on the supply STW start time. As the start time in this scenario is based on the STW norm time the on-time Buf percentage cannot be compared to the current state model. The performance itself is presented but the comparison will not be made.

The norm time planning shows an increase in both the on time performance and the productivity, as is shown in table 7.4. Again it is seen that the performance in the more busy test cases increases the most. As the norm time only changes the order in which the STW are processed it was expected the model behaves more or less the same. To verify this in more detail the other outputs will be discussed as well.

The detailed outputs for the norm time planning are shown in table 7.4. Most outputs show increased performance, except for the expansion factor. Especially in the bottom line test case the expansion factor increases a lot. Looking at the actual value the expansion factor seems to be constant for all three cases. This suggests that the norm time planning does not have influence on the last step in the process. This is expected as only the sequence of execution is altered.

The duration of the distribution process decreases, and as the workload becomes higher this effect becomes more evident. The same is seen for the total distribution time. Looking at the average lead time it is seen that in the bottom line test the lead time increases, while for the other two cases this lead time has decreased. This was also seen at scenario one, but zooming in on the step times (figure 7.5) shows a different pattern.

Table 7.4: KPI's and outputs for Scenario 2: Norm Time Planning with Improved Control

	Test case	Current state model	Norm time planning	Difference [%]
<b>KPI</b>				
On-time performance (Wis)	Bottom line	96,2%	97,1%	1,0%
	Base line	92,9%	95,8%	3,0%
	Top line	86,6%	94,5%	9,1%
Productivity	Bottom line	32,72	32,86	0,4%
	Base line	32,21	32,87	2,1%
	Top line	32,21	33,50	4,0%
<b>Detailed outputs</b>				
Expansion factor	Bottom line	1,68	1,93	14,8%
	Base line	1,78	1,91	7,1%
	Top line	1,91	1,93	1,0%
Duration Distribution	Bottom line	3,80	3,72	-2,0%
	Base line	5,38	5,19	-3,6%
	Top line	6,54	6,19	-5,3%
Total Distribution Time [hr]	Bottom line	655,3	652,3	-0,5%
	Base line	1123,6	1101,5	-2,0%
	Top line	1506,5	1447,7	-3,9%
Average lead time [hr]	Bottom line	1,22	1,23	0,6%
	Base line	1,37	1,36	-0,8%
	Top line	1,49	1,44	-3,2%
On Time Buf %	Bottom line	99,1%	99,9%	N/A
	Base line	87,2%	92,5%	N/A
	Top line	72,5%	85,8%	N/A

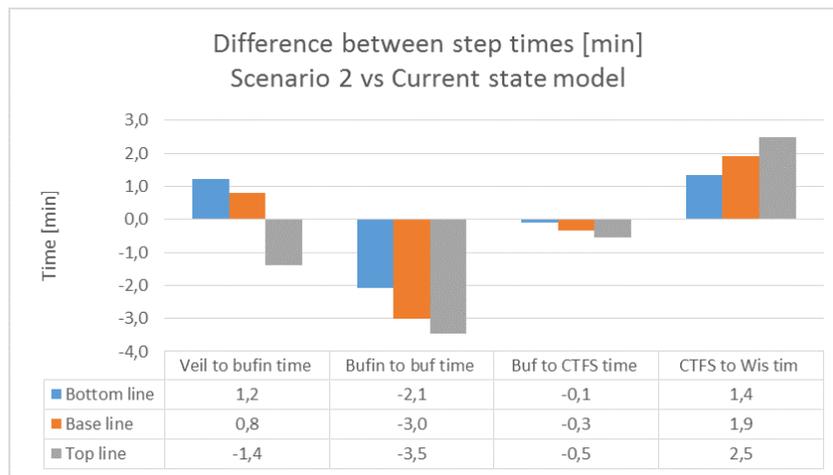


Figure 7.5: Difference in step time of scenario 2 compared to the current state model

The time a logtra on average spends in the storage has increased, except for in the top line case. The time a logtra on average spends in the buffer has decreased with a couple of minutes. The average lead time is not affected that much, which indicates this is solely a shift between these two steps. As STW with more logtra on them will take longer to process these are picked from the buffers earlier. As these STW carry more logtra this has a bigger impact on the average time a logtra spends in the buffer. The norm time planning prioritizes STW with more logtra, sending them through the buffers quicker. This is expected to result in the recorded shift between these steps.

## 7.5. Scenario 3: Client Demand Planning

In the third scenario, the client demand planning uses a different format for the organization of the auction and the process. This should result in a higher performance on both on-time delivery and productivity. Also a more constant process with a shorter lead time is expected.

As the format differs from the previous ones it is more difficult to compare the results with the current state model. First of all the on-time Buf performance cannot be compared to the current state model since norm time planning is included in this scenario as well. Secondly the client demand planning aims to finish the process in eight hours, therefore the duration of the distribution is compared with this as target time.

Thirdly as the auction takes place prior to process and the delivery time is no longer based on the auction time, it is irrelevant to measure lead time over these steps. As the rate of filling the buffer also is changed for this scenario this is excluded as well. Therefore the time from Buf to Wis is presented instead (Buf-Wis time). This has been done for the current state model as well, making a comparison between the two possible again.

The test results for scenario three are given in table 7.5. The scenario improves the performance on on-time delivery and the productivity significantly.

The on-time delivery performance is a 100% percent for the bottom line and base line test case. In the top line test case the on-time delivery is 99,5%, indicating that the fixed time blocks are occasionally exceeded. Looking into the individual test runs shows that the minimum on-time delivery performance is 94,8%, and fourteen from the hundred test runs score less than 100%.

Table 7.5: KPI's and outputs for Scenario 3: Client Demand Planning with Improved Control

	Test case	Current state model	Client demand planning	Difference [%]
<b>KPI</b>				
On-time delivery (Wis)	Bottom line	96,2%	100,0%	4,0%
	Base line	92,9%	100,0%	7,6%
	Top line	86,6%	99,5%	14,9%
Productivity	Bottom line	32,72	33,97	3,8%
	Base line	32,21	33,52	4,1%
	Top line	32,21	33,83	5,0%
<b>Detailed outputs</b>				
Expansion factor	Bottom line	1,68	1,50	-11,1%
	Base line	1,78	1,51	-15,1%
	Top line	1,91	1,53	-20,0%
Duration Distribution (Planned duration of process)	Bottom line	8 (planned)	6,96	-13,0%
	Base line	8 (planned)	7,50	-6,3%
	Top line	8 (planned)	7,79	-2,6%
Total Distribution Time [hr]	Bottom line	655,3	631,1	-3,7%
	Base line	1123,6	1079,8	-3,9%
	Top line	1506,5	1433,7	-4,8%
Buf-Wis time [hr]	Bottom line	0,48	0,95	97,9%
	Base line	0,42	0,73	73,8%
	Top line	0,37	0,64	73,0%
On Time Buf %	Bottom line	99,1%	100,0%	N/A
	Base line	87,2%	100,0%	N/A
	Top line	72,5%	99,9%	N/A

The productivity is the highest in the bottom line test case and the lowest in the top line test case, which is opposite compared to the previous results. As a result of the fixed duration time the workload per hour in the bottom line test case is very low, and as a result fewer distributors are deployed leading to less interference between different distributors. This can be seen in both the waiting time and the number of positions used. As the workload is so low in the bottom line case only 910 positions are required compared to 1064 in the top line test case, and the waiting time in the bottom line test case is only 3,5% of the total distribution time while this 7,5% of the total distribution time for the top line test case.

In table 7.5 the detailed output are presented. These are adjusted as explained since the client demand planning differs from the other scenarios.

The first thing that stands out is the expansion factor, which has been decreased with 10% to 20% compared to the current state model. This improved performance is an effect of the bundled logtra per client. As all logtra for a client are processed in the same time block, it will become a rare event for an STW to be forwarded before it is filled to its max. This keeps the expansion factor low.

The duration of the process is shorter than the planned eight hours. As the norm time per STW is an estimation it can differ from the actual time required. The norm time estimation seems to be on the high side as the average duration is significantly shorter than the planned 8 hour duration. The difference becomes smaller as the work load increases, which can be

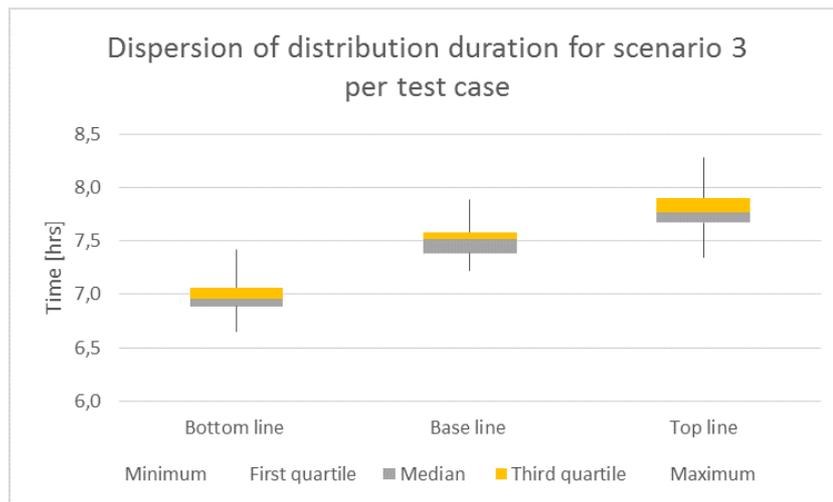


Figure 7.6: Dispersion of the duration of the distribution process for client demand planning

explained looking at the waiting time. As discussed in the previous section the waiting time share in the total time increases with the workload, however this is not taken into account in the norm time calculation.

Also the workload is not spread equally over the time blocks, as clients can buy more or less than expected. These fluctuations are present in the model and also contribute to the dispersion in the duration of the process. The dispersion is shown in figure 7.6. First of all the middle 50% of the data lies close together, suggesting quite stable performance. Secondly the dispersion is less than one hour in all three cases. Only the value increases as the workload increases, and in the top line case the eight-hour mark is exceeded 14 out of 100 as mentioned earlier.

The total deployed hours for the distribution decrease using client demand planning. This is caused by the reduction in waiting time. The waiting time is reduced by the bundling of logtra per client per time block in combination with the dynamic path position control.

## 7.6. Final Results

In this section the three scenarios will be compared and the results of all tests will be evaluated. The current state model will be included in the comparison as well.

### KPI Results

First the performance of the scenario's on on-time delivery and productivity is discussed as these are the most relevant. In figure 7.7 the on-time delivery performance is presented, comparing all three scenarios with each other and the current state model. In figure 7.8 the same setup is used to present the performance on productivity for these scenarios.

#### On-Time Delivery

Looking at the on-time delivery the figure clearly shows an improvement of each scenario compared to the current state model. The client demand planning scenario (3) shows the most improvement and is able to an on-time delivery percentage of well above 95% in all three test cases.

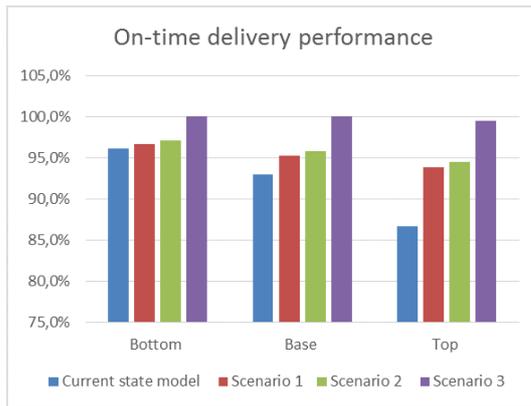


Figure 7.7: On-time delivery performance

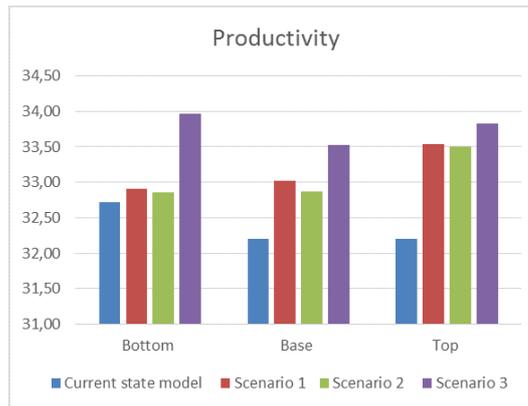


Figure 7.8: Productivity

Further it is noticed that scenario 2 and 3 show a similar increase in the performance. The norm time planning performs only slightly better than the current state planning. The results also show that the increase in performance is the largest in the busier test cases.

### Productivity

The performance on productivity (figure 7.8) is also increased with all three scenarios. Scenario 1 and 2 realise about the same increase in productivity, but this time the current state planning performs slightly better than the norm time planning. For these two scenarios also the improvement is the highest in the busier test cases.

The opposite is seen in the performance of scenario 3. Again in all three test cases the productivity has gone up, but not the highest increase is realised in the more quiet bottom line test case. Nonetheless does scenario 3 outperform the other scenarios when it comes to productivity.

## Detailed Results

The performance of the different scenarios is compared in more detail in this section. Relevant outputs for all three scenarios are selected to do this. The presented outputs apply to both the client demand planning structure as to the other structures.

### Expansion Factor

While the performance of the individual scenarios was discussed it became clear also the expansion factor was affected. This is not included in the KPI's for this operation, however it is an important factor of the process as this determined the amount of work created for delivery department.

The performance on the expansion factor is presented in figure 7.9. Scenario 2 and 3 show the same results as one another and also no difference in the performance between the three test cases is recorded. In these scenarios the expansion factor seems not to be influenced anymore by the workload. The dynamic path position control distributes the logtra over the all available positions in the path, causing an increase in the expansion factor.

In scenario 3 improvement in the performance is seen as the expansion factor decreases to about 1,5. Again this value is stable and independent of the workload. In this scenario the logtra are bundled based on the client which results in the lower expansion factor. Also, an

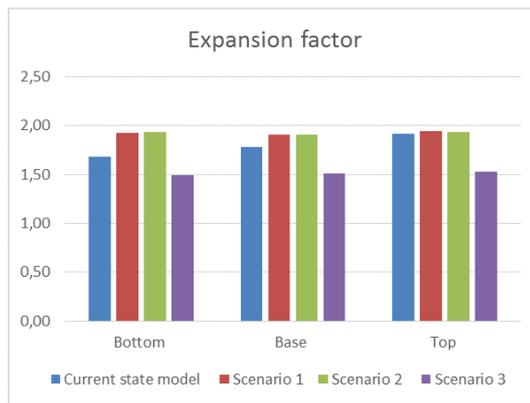


Figure 7.9: Expansion factor

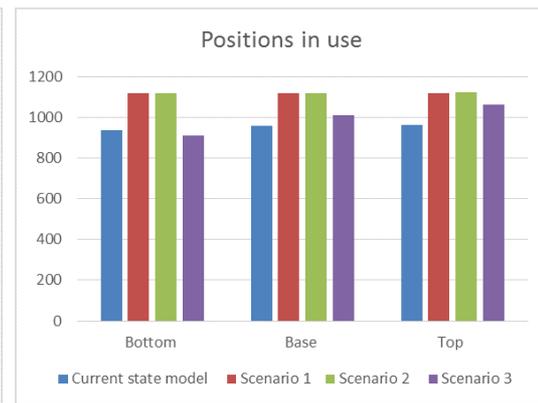


Figure 7.10: Number of positions used in the operation

unfilled buyer STW will not be changed until the end of each time block, giving other logtra more time to end up on the same buyer STW.

Where the dynamic path position control negatively effects the expansion factor in scenario 1 and 2, this is turned around into a positive effect in scenario 3 by bundling logtra for the same client.

### Positions in Use

The dynamic path control increases the number of positions used in the process (see figure 7.10). This minimized the waiting time which positively effects the on-time performance and the productivity. However this also what increases the expansion factor in scenario 1 and 2. This can be seen in the figure as the number of positions used is constant for these scenario's.

Scenario 3 shows a different effect on the number of positions used. With the logtra bundled per client, but spread out over a longer process time the number of positions required is reduced.

Scenario 1 and 2 show to use the space more optimal as almost all 1122 available positions are used. This positively effect the performance. Scenario 3 does not used nearly as much positions but sill produces better performance and decreases in the expansion factor as well. As not all positions are used this shows possible room for improvement for the path position control.

### Waiting Time

Figure 7.11 shows the total waiting time in the distribution. The current state model performance shows that the waiting time increases strongly when the workload increases. The waiting time is less in all three scenario's. Again, scenario 1 and 2 perform more or less the same. The waiting time in scenario 2 just slightly higher although this not significant. Scenario 3 performs a bit better as the waiting time is the lowest.

### Buf to Wis Time

As the lead time is irrelevant for scenario 3 it was chosen to use the time between Buf and Wis, the last two steps in the process, as an alternative for comparison. Figure 7.12 shows the average time between these two scan moments. Scenario 1 and 2 show a slight increase compared to the current state model whereas scenario 3 shows a major increase. Scenario 3 uses time blocks and each logtra is allowed to wait in the path till the end of a time block. As block of 1 hour are used the allows waiting for the last steps is much longer, and as this is

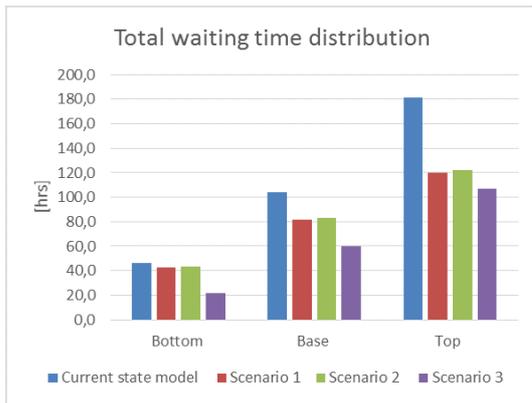


Figure 7.11: Total waiting time distribution

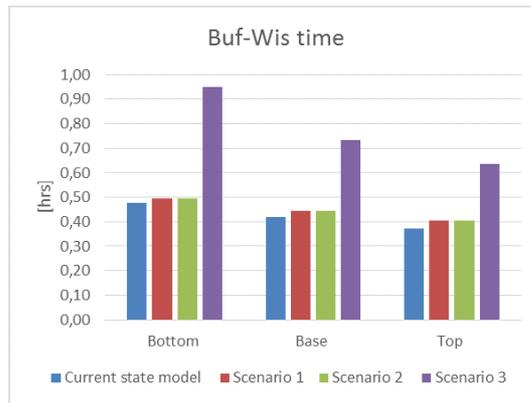


Figure 7.12: Buf to Wis time (alternative lead time)

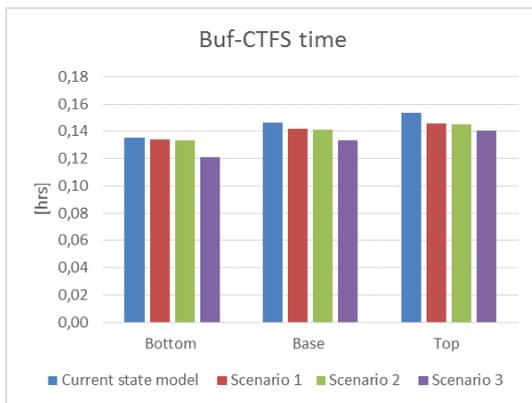


Figure 7.13: Step time from Buf to CTFS

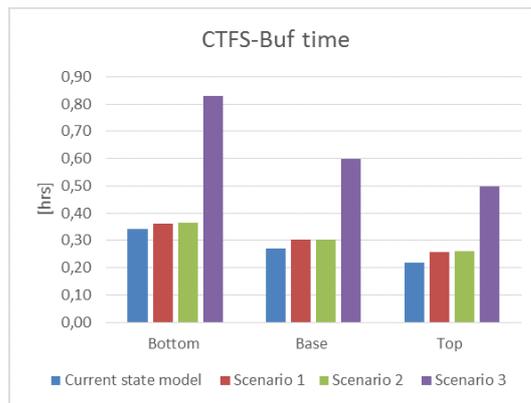


Figure 7.14: Step time from CTFS to Wis

used regularly the time between Buf and Wis has been increased tremendously. To further investigate this effect these two steps are discussed individually as well.

### Buf to CTFS Time

Figure 7.13 zooms in on the step time Buf to CTFS. This is the step in which the distributor picks up a STW from the buffer and places each logtra individually on a buyer STW. The figure shows a small decrease in step time for all three scenario's. Scenario 3 shows the most improvement. The improvements increase for each of the scenario's. As the effect of the controls increases with the workload this was expected.

### CTSF to Wis Time

Figure 7.14 shows that step time for the final step. Here the logtra waits in the path until its buyer STW is forwarded. This can be done because it is full or because a logtra on it has reached its maximum forward time. As explained earlier the client demand planning scenario uses a different, later, maximum change time for each logtra. This allows the logtra to stay at this step longer, increasing the CTFS to buf time. As can be seen this impacts the lead time a lot.

The other scenarios also show a slight increase of time used for this step. This is caused by the dynamic path position control, spreading the logtra over more buyer STW, decreasing the chances it is forwarded because it is full.

## 7.7. Synopsis

The following sub research question has been answered in this chapter.

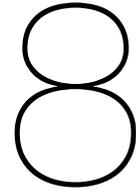
- *What impact do the design options have on the performance of the order handling process?*

The results from the different tests were discussed in detail. First the proposed controllers are tested individually to study their effects. As both controls positively effect the KPI's both controls are used in the improved control in all future state scenarios.

The future state scenarios were tested and discussed individually. The changes in the outputs are compared to the performance of the current state simulation model and discussed. More detailed analysis of the performance is done to declare the behavior. All scenarios improve the performance of both KPIs.

Finally the three scenarios are compared on the same criteria. Looking at the KPIs all scenarios positively effect the performance, but scenario 3 realises the most improvement.

In the next chapter conclusions will be drawn from these results.



# Conclusion and Recommendations

In this chapter the findings from the research are concluded. First the main research question is answered, followed by recommendations for future research and a review of the work.

## 8.1. Conclusion

This research studied the process at Royal FloraHolland to give an answer to the following main research question:

*"How can the performance of the order handling process at Royal FloraHolland flower auction in Aalsmeer be improved through re-design of the information system?"*

The 'information system' is defined as the aspects involved in planning and coordinating the process. Hereby the focus lies on what information is used and how it is used. Based on theory and the findings from the process analysis improved controls and new planning strategies were proposed and combined in three future state scenarios. A simulation model was developed to test the impact of the proposed changes in three different test cases.

Task assignment control is proposed to improve the effectiveness of the distributors. By assigning tasks to the individual workers the planning is executed better resulting in an increased on-time delivery performance up to 4,4%. The control is most effective when the workload is higher. Tests with the model confirm the controls increase this performance. The control only effects the order in which the work is done and not how much work is done, therefore no change in the productivity is measured.

Dynamic path position control is proposed to minimize waiting time due to congestion of distributor in the paths. The results from the simulation tests shows that the control is able to achieve this by using the available space more efficiently based on work in process per client. This improves the productivity of the distributors, shortening the overall process time and improving the on-time delivery performance as well.

The first scenario makes use of both controls in combination with the current state planning. The combination of the two controls together has shown to realise a bigger increase in performance compared to the individual controls. Both controls seem not to be effected by the other as the combined results are close to the sum of the individual controls. This combination has proven to increase the performance effectively.

In scenario two the two controls are combined with a more detailed planning, based on an estimated process time of each task. This was thought the increase the on-time delivery even

more, however the simulation test show no significant increase. As it has neither a positive nor a negative effect on the performance the scenario still improves the current state performance but the proposed planning does not seem to contribute to the increased performance.

In the third scenario the client demand planning, based on pull theory, is proposed to make a more realistic and achievable planning possible by delivering based on client demand instead of delivery based the moment of purchase. The combination of this planning and the two controls results in improved performance for both the on-time delivery and the productivity. The client demand planning relieves pressure of the distribution process which increases the productivity. As distributors are planned based on actual the workload per time block close to perfect on-time delivery is achieved.

The proposed future state scenarios show that through re-design of the information system it is possible to improve the performance, a different ways to achieve this are proposed.

## 8.2. Discussion

The simulation model used has some limitations since it is a simplified representation of the process. First of all it was observed that the human factor plays a in most processes. In the distribution some STW are preferred over others resulting the selection from the buffers. In the path manager process it is seen that buyer STW are forwarded early based on their personal experience. These actions are not modeled. Additionally errors causing rework or damaged products are not taken into account.

The auction process has been modeled as a continuous stream of random transactions. However this process is subjected to more detailed fluctuations. Per auction group the split factor may well differ as some products come in smaller packaging. This can create significant waves of supplied STW with longer norm times. These effects have not been taken into account in the model.

The norm time calculations are made using a simplified model based on the norm time model from Royal FloraHolland. Since the transactions are not given all features the norm time calculation can be off. This might effect the norm time planning results.

The task assignment control directs the distributor to a specific task but it is also assumed that the right task is always available at the front of the buffer. This requires sorting the STW when they enter the buffer. Since FiFo tracks are used there is a limit to what can be sorted. If the supply STW are mixed badly sorting them will not be possible any more. In the model this has not been taken into account and perfect sorting has been assumed.

For the future state design only simple reactive controllers have been considered. These controllers are designed to take simple discussions based on limited information and predefined decision values. These have not been optimized.

## 8.3. Recommendations

Based on the previous conclusions, some recommendations can be made. First of all it is recommended to further develop the client demand planning concept. The concept has proven to have great potential to improve the performance of the oder handling process. However it also requires the most changes to the current setup and the adjacent processes. Therefore it should be researched what the impact of this concept is on both the presorting of the supplied STW, and the auction process as is discussed.

Another aspect from the client demand planning concepts to further develop is the time block structure. It is recommended to test different durations and amounts of time blocks. The currently proposed structure with eight blocks of one hour has not been optimized. In this process the clients also should be involved to clarify what kind of structure suits their operation best. Additionally the impact of the number of time blocks on the required pre-sorting before storage has to be investigated.

For the client demand planning the norm time estimation for supplied STW is used for the planning of the required number of distributors. The process often finished well before the eight hour mark indicating an overestimation on the norm time. Large fluctuations were measured indicating inaccuracy in the estimation. Since the difference becomes smaller as the work load grew it is expected that the congestion due to the number of distributors plays a role in this. Therefore it is recommended to develop a more accurate norm time estimation including a congestion factor.

Furthermore, the dynamic path position control has proven to be effective when it comes to improving the on-time delivery and the productivity. However, it also increases the expansion factor resulting in more work further down the line. It is recommended to investigate how the controller can be adjusted minimize the increase of the expansion factor while remaining its positive effect on the overall performance of the order handling.

Finally the flower auction order handling is a process that experiences great fluctuations in workload due to factors like seasonality of both the supply and the demand, but also the great variety of different products to be processed. Therefore lots of potential is seen for the use of controllers to deal with these fluctuations.

## 8.4. Reflection

In this report the possibilities to improve the order handling process performance through re-design of the information system are investigated, and the results are promising. However, creating a simulation model requires to make assumptions as the model is just a simplified representation of the real situation.

In the process at Royal FloraHolland the human factors play a significant role. This is difficult to capture in a model as this is often hard to predict. Using data it is possible to validate the current state behavior. However this is not possible for future state scenarios as there is no data on the real life performance available. For these reasons there will always be some uncertainty in modeled results.

For the presented model it was difficult to recreate the behavior of the path manager as these workers use their experience to manage the buyer STW and logtra in their path. The experience includes knowledge of the process, the clients, and the ability to structure and create overview for themselves. This is difficult to capture in a model.

The model has some limitations as not all possible situations are presented in the model. Congestion is modeled as distributors waiting for the same position. However, when a path gets too crowded it could also occur that a distributor waiting for a position blocks access to another position. This can create more holdup in the real situation, but this is not taken into account as this effect is estimated to be limited.

The practical value for the research is that using the model it is made possible to create better insight in the functioning of the process, and the effects the proposed scenarios and controls have on the operation. These results can be used by Royal Flora Holland to select viable options to explore further and improve the process with.

This research is also considered to be scientifically relevant. Theory on lean manufacturing originates from the manufacturing industry, and has proven itself in such environment. Currently lean theory is applied in many more fields as it turns out to be wider applicable. Also in logistical processes lean manufacturing is used more and more. The process at Royal FloraHolland is a unique process, similar to warehousing or DC logistics but with several unique additional restrictions. Lean theory has been applied in this research and has been used to create future state scenarios, working towards a pull bases logistics system. This resulted in higher performance of the process. Therefore the theory has proven itself to be applicable, also in these unique conditions.

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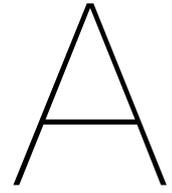
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# Scientific Research Paper

# Re-design of a Current State Push Based Towards a Future State Pull Based Logistic System for Royal FloraHolland

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**Abstract**—The performance of the logistical process from the flower auction at Royal FloraHolland is under pressure. Due to decreased transaction sizes more handling is required to process the same volume and this results in lower performance. The information system used to coordinate the process is based on a fixed relation between auction and distribution which limits the control over the process. In this paper it is investigated how the performance of this process can be improved by re-designing the information system. The process and the current information system are analysed after which three future state scenarios are proposed building up to a pull based logistic system. Two controllers are proposed that increase coordination in the process and use a dynamic structure to deal with local congestion. Also two planning strategies are proposed. The first one within the restriction of the current throughput time criterion, and the second one breaking this open and working towards the client demand. A simulation model of the process is made to test the proposed future states. The future states are tested using different test cases with varying workload. The results from the tests are promising as the performance is improved. Further research is recommended to optimize the controls and to develop the client demand planning in more detail.

## I. INTRODUCTION

Royal FloraHolland plays a major role in the horticultural trade. The flower auction is an important aspect of their operation in which they bring supply and demand together. The flower auction in Aalsmeer is one of the largest in the world where on a daily basis over 30.000 transactions are created. These transactions are processed as soon as possible after the moment of purchase. This puts high pressure on the order handling process. As a recent development the transaction size has gone down which results more transactions to process for the same amount of supplied volume. This has caused the performance to go down as the on-time delivery now has dropped below the 95% norm. The cooperation is working on digitalization of the processes it would like to discard of the paper order tickets in the order handling process. These tickets created a static process coordination that was not able to use real time information from the process and deal with fluctuation in the process. Discarding the use of the tickets opens up possibilities to re-design the information system for this process in order to improve the performance.

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## II. METHOD

The order handling process will first be analysed using techniques from lean manufacturing theory. The process and the role of the current information system is mapped to create insight in the process. The current performance of the operation is also analysed in detail. After this a discrete event simulation model of the current state will be created. This will contribute to understanding the process and is later used to test proposed improvements. Based on the findings from the analysis and theory from literature an ideal state is drawn up. With this in mind improved controls and planning strategies are be designed and combined in three future state scenarios. These scenarios are tested in the simulation model under different conditions and the results are discussed.

## III. ANALYSE

The order handling process of the flower auction starts simultaneously with the auction itself. Before the auction start all the products are delivered to the auction on a standardized trolley (STW) and placed in storage. In the same order as auctioned the STW are retrieved from storage, brought to the distribution area and placed in one of the buffers. In this area around 250 distributors drive around on small electro tractors. A distributor picks a STW from the buffer and drops of all transactions on the STW at designated location in the distribution area assigned to buyer. The distribution area consists of a 250 meter long driveway with 50 paths on either side and each path contains about 22 drop off locations assigned to specific buyers. At these locations an empty STW, referred to as buyer STW, waits to be filled with transactions for its buyer. Once full or when one of the transactions on it the buyer STW is past its forward time the buyer STW is forwarded to the delivery, where all finished buyer STW are combined into train and delivered to the buyers location within the building. The order handling process runs from when the products leave the storage up to the point where they are forwarded to delivery.

The performance of the process is measured with the on-time delivery percentage and the productivity and these are used as the KPI. On-time delivery is the percentage of transactions that reaches the delivery step on time, and is important as it indicates the quality of the service delivered to the client. Currently a throughput time criterion is used which determines that the transactions should be at the

delivery within two hours measured from the moment the transaction was made at the auction. For a small percentage of the transactions the throughput time of four hours is used. The productivity of the order handling process is measured as the number of transactions processed per deployed hour in the distribution and gives information about the efficiency of the operation.

The analysis has shown multiple areas to improve the process on, both in the overall structure of the process as well as in the detailed organization of the process. The process is push based and the auction determines the workload and the time schedule for the distribution. As the auction pushes out transactions at a higher rate then the distribution can handle a backlog builds up. The delivery moment is based on the purchase moment of the transaction and because of this the total number of transactions created at the auction determines what performance can be achieved in the distribution process. It is also found that the distributors regularly are waiting to deliver a transaction because the drop off point is occupied by another distributor. With the 1122 possible drop off points and only at most 280 distributors active at the same time this seems avoidable. Also it was found that the information distributors can use to select the next task to perform is limited resulting in larger fluctuations in lead time. This makes the distributors less effective when it comes to on-time delivery performance. Each transaction also is given a time planning based on the moment of purchase. A standardized planning is used, not taking into account the actual client demand, nor the actual process time of supplied trolley the transactions arrives on.

#### A. Simulation Model

A simulation models was written in Pascal [1] using Delphi using TOMAS [2] to make discrete event simulation possible. the model represents the oder handling process as was just described and simulates a single day's work in one run. The number of supplied STW and the number of distributors active can be given in to test different workloads. The model keeps track of the on-time delivery performance and productivity as well as several other outputs like the average lead time, the expansion factor, and waiting time of distributors.

The model has been verified and validated. For the validation of the model's performance operational data from Royal FloraHolland from the period of September 2016 until August 2017 was used. Three data sets where developed for the validation presented as a bottom line case, a base line case and a top line case. These cases represent different levels of workload. Together with the people from Royal FloraHolland several outputs besides the mentioned KPI were selected for the validation. The model reproduces the validation cases with an accuracy of 3.2%.

## IV. DESIGN

To improve the performance of the order handling process several future state scenario were developed. First an ideal state was developed, based on lean theory of pull and adding value [3], [4], [5]. The ideal state focuses on the added value for the client delivering what he wants, when he wants it.[5] To achieve this the ideal state uses a pull based structure in which a client places an order list triggering the planning of the physical order picking process, reasoning backwards from the delivery moment to calculate the required start of the activities.

The future states were developed based on the ideal state, but now with the restrictions of the unique Royal FloraHolland situation is mind. Two new planning strategies were proposed. Norm Time Planning is operating within the current setup in which the auction and order handling are connected through the throughput time criterion and creates a more detailed planning based on the characteristics of each STW. The other planning is the Client Demand Planning in which the auction and oder handling process are cut loose to enable more elaborate planning. It was found that in order to implement these planing strategies, additional control was required to follow the planning and therefore the Task Assignment Control was proposed. Also to improve the process flow and minimize the waiting time the Dynamic Path Position Control was designed.

#### A. Task Assignment Control

The task assignment control coordinates the order in which STW are picked from the buffer. Each STW is already given a start time. The first thing the control does is sort the STW entering the buffer over the buffer tracks based on start time. The second thing it does is assign a distributor arriving at the buffer side to a specific buffer and buffer track.

#### B. Dynamic Path Position control

The dynamic path position control will minimize waiting time by using the path positions (drop off points) more efficiently. The control makes it possible to switch the 'owner' (assigned buyer) of these positions to avoid waiting line at the positions. If the number of transactions on the way to buyer exceeds a certain value the controller will bargain for an extra position. If possible it is grated. Action like this is only take when a distributor arrives while its buyers position is occupied to avoid unnecessary shifting of owners.

#### C. Norm Time Planing

Currently the start time for an STW is the auction time + 1.5 hours. As some STW only have to be dropped off as one while others contain more then 10 transactions to drop off the time per task differs a lot. This time is called the norm time, and can be estimated for each STW based on its content. This is used to determine a more accurate

start time calculating backwards from the planned delivery moment. The STW are automatically processed based on the start time with the task assignment control. This should result in more transaction arriving on their destination on time.

#### D. Client Demand Planning

Client demand planning let go of the restriction imposed by the throughput time criterion. A delivery schedule is constructed of 8 time blocks of 1 hour. Each buyer is assigned to a time block and all the transactions for that client will be processed in that time block. The auction now takes place some time prior to the distribution process so that all transactions are known in advance. It is assumed that all transactions are stored only with other transactions assigned to the same time block. The number of distributors per time block are planned based on the workload and the sum of the calculated norm time. The dynamic path position control is essential as every hour different buyers require positions to receive transactions. With this planning strategy the transactions are bundled per buyer and can be delivered to the buyer in a predefined time slot.

Three future state scenarios were proposed. In each scenario both the controls as discussed above are used in combination with a different planing strategy. The scenarios are:

- Scenario 1: Current state planning
- Scenario 2: Norm time planning
- Scenario 3: Client demand planning

### V. RESULTS

The performance of each of the scenarios in the conditions of the test cases was tested using the model. The results showed that all three proposed scenarios improve the performance of the order handling process. The results are depicted as the improvement of the performance per KPI compared to the current state model. The three test case use inputs as given in figure I. In the third scenario the number of distributors is planned in the simulation per hour of distribution.

TABLE I  
INPUT VALUES PER TEST CASE

	Supplied STW [%]	Deployed distributors
Bottom line	8643	268
Base line	6714	247
Top line	4205	214

#### A. Control Testing

First the controls are tested individually to verify both function as planned and have a positive effect on the performance. These tests indicated that the task assignment control improves the on-time delivery directly. The dynamic path position control reduces the waiting time, causing an

increase in the productivity and a decrease in lead time with higher on-time delivery performance as a result.

#### B. Scenario 1

The use of the two controllers together resulted in an improvement of both the on-time delivery performance and the productivity. The results are presented in table II. The effect of the controls are largest in the top line test case, which is positive since in this scenario the performance was the lowest. As less distributors are active in bottom line test case less waiting time will occur automatically decreasing the effect of the dynamic path position control. Also the task assignment control has less effect as with the lower workload less backlog builds up.

TABLE II  
IMPROVEMENT OF SCENARIO 1 COMPARED TO CURRENT STATE MODEL

	On-time delivery [%]	Productivity
Bottom line	0,6%	0,6%
Base line	2,5%	2,5%
Top line	8,3%	4,1%

#### C. Scenario 2

In scenario 2 the current state planing is replaced with the norm time planning. The results are displayed in table III This scenario also improves the performance on both KPI. The results are comparable to the results of scenario 1. Again the effects of the proposed scenario are more evident in the busier test cases. The on-time delivery is improved a bit more compared to scenario 1 while the productivity is improved a bit less compared to scenario 1. This suggests that the norm time planning has limited effect on the performance compared to the current state planning.

TABLE III  
IMPROVEMENT OF SCENARIO 2 COMPARED TO CURRENT STATE MODEL

	On-time delivery [%]	Productivity
Bottom line	1,0%	0,4%
Base line	3,0%	2,1%
Top line	9,1%	4,0%

#### D. Scenario 3

The client demand planning used in scenario 3 results in a significant increase of performance in all three test cases as can be seen in table IV. The client demand planning creates more time for the execution resulting in less distributors to be deployed at the same time, adding to the positive effect the dynamic path position control has on the productivity. Also the on-time delivery is improved a lot giving almost perfect performance. This is a result of the detailed planning that is able to calculate the required amount of distributor quite accurately. An important aspect is that most of the time the number of distributors required is well under the

maximum capacity that was normally used in the top line case. This is possible because the workload is spread over 8 hours instead of the 6 to 7 hours in the current state.

TABLE IV

IMPROVEMENT OF SCENARIO 3 COMPARED TO CURRENT STATE MODEL

	On-time delivery [%]	Productivity
Bottom line	4,0%	3,8%
Base line	7,6%	4,1%
Top line	14,9%	5,0%

## VI. DISCUSSION

In the simulation model mistakes or errors are not taken into account. It happens that a distributor drive to the wrong location, or drops products. Also the process of when a buyer STW is forwarded is simplified as the human factor made it hard to simulate. Experience and personal preference play a large role in how the step is executed in the real process. Also seasonal patterns are not modeled although this effects the supply. The products put op for auction differ per season, and different products result in different content and buildup of an STW.

## VII. CONCLUSIONS

In the proposed scenarios the information system was re-designed to improve the performance of the operation. The results from the simulation tests show that each of the scenarios improve the performance on both on-time delivery and productivity. Client demand planning provides

a structure in which the performance is less dependent on the workload provided by the growers. The controls both are essential for the results achieved in the scenarios. The task assignment control enables execution of more detailed planning while the dynamic path position control minimizes the waiting time for distributors. The client demand planning would not function without a dynamic path position control as the layout of the path positions changes completely every hour. The scenarios show different ways of how the process performance can be improved through re-design of the information system.

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# B

## Process Description

### B.1. Process and Information Flow

Logistical transaction information is vital for the execution of the process. This section will show where the information used during the process comes from. This requires to look further back in the process than the areas that this research focuses on. Specific process steps will be discussed in more detail as well.

In figure B.1 the order handling process is shown, including the step leading to the placement of supplied STW in storage and the auction. Before arrival a batch of products is already announced by the growers to allow reservation of storage space to be planned by the auction. Once the products are delivered the 'KoWaLa' scan is made, that links the products on a supplied STW to the STW ID in the database (02).

The auction schedule is made shortly before the auction starts. This also determines the order in which STW are retrieved from storage. At the auction (05) transaction information is generated which includes the buyers details, the product details and the amount purchased. Also a time stamp of the purchase moment is registered ('VEIL').

Using the transaction information and the KoWala information the logistical transactions are created, containing all the information for the execution of the transaction such as number of buckets, location to transfer, sorting details, client address and the time schedule. With this information in the data base the order handling process can start.

#### B.1.1. Retrieval from Storage

Following the order the products are auctioned they are retrieved from the storage areas and using the automated chain conveyor transported to the distribution area. Some variation will occur as this is done in batches since there are only 5 transport lines to the buffers while there are then auction clocks. The STW are arranged along tracks and are disconnected from each other. A vehicle is used to push the STW from one track slowly to the chain conveyor where a worker slides them one by one in the chain conveyor track. The chain conveyor hooks on to an STW every meter or so, creating a continuous line of STW moving towards the buffers.

About 50 to 100 meters before they reach the buffer they pass over an RFID antenna, detecting the tag and signaling the STW ID to a controller. The corresponding transaction data for the STW is gathered and sent to the printer (figure B.1 at 06) located further down the line. For each transaction an order ticker is printed as shown in figure B.2. The ticket contains a lot of information, including details about the products, the price, the quality, the

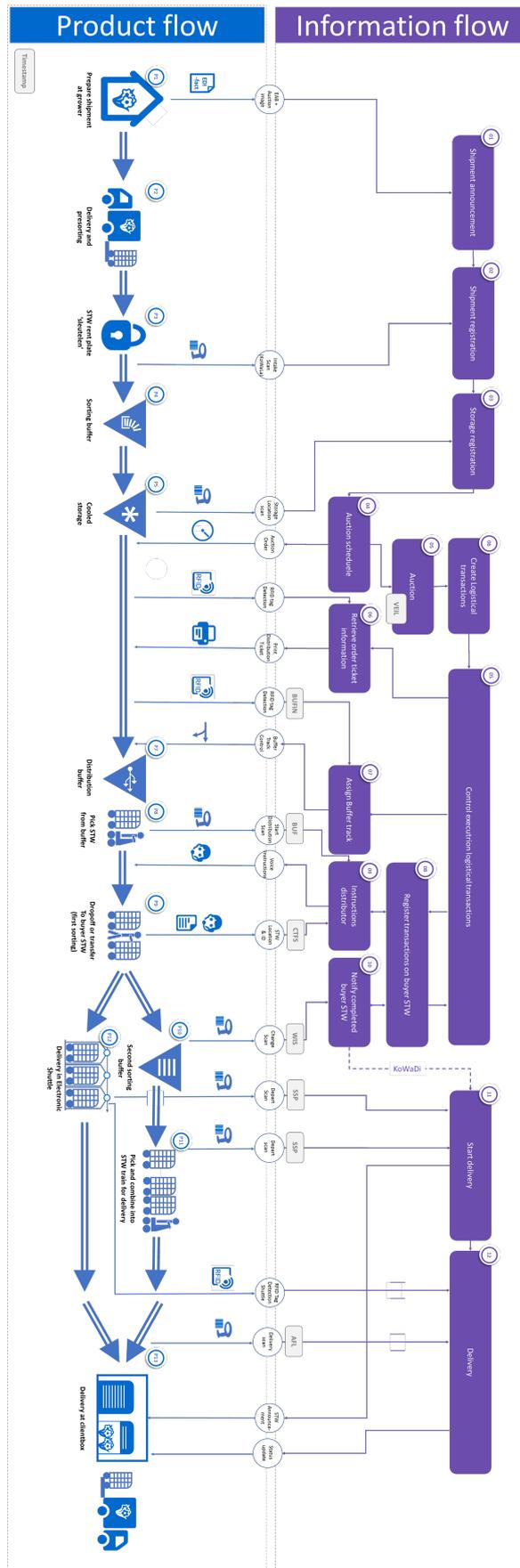


Figure B.1: Flow of information through the process

OP		GPS/6		STW NUMMER		FUSTEN		PARTIJ TRANS		STATUS	
25-16		03/11		06:26		07:56		005958		18 1 3	
PRO. VERDEEL.NUMMER		DAG		VELTID		INLETTID		WISSELTID		RESE. BUS	
11099a		4		83007		11095		C		3 0	
PARTIJ		ALVON		AMWOFDEENR		BRIEFVOLDNR		VEEDROEP		TRANSDIEN	
136		55		23		0		0		340	
FIBT		A.FE.		BDR-1		TRANSACTIEER		PRODUCTNAAM			
997		40		75		705-01 0		EUS G ROSI WHITE			
REKON		PKR		BDRF2		BDRF3		BDRF4		REUR-1	
20024		40		0		0		0		MPS B	
AITECODE		A.FE.		PRIM		RUBT		MUNT		MNTAL	
40						997		1c		ALBLD	
B: 02		C: 05		0103308007050100004				ZETEL		PLAAT	
06:26		004-E		Dijk Bloemen BV van				2833		1203 424027	
DAG		SPOEDNUMMER		AFLEVERPUNT				AFLEVERADRES			
Do		87		004-15							

Figure B.2: Order ticket for logistical transaction

grower, and relevant information of the particular transaction like the amount and where to process the transactions.

Two worker operate the printing station. Often one separates the stream of printed tickets per STW, indicated with a thick line on the last ticket belonging to the same STW. The other one places the tickets at the right STW as they check whether the STW ID on the trolley corresponds with the one on the tickets. The tickets are places on the trolley at the right hand side around middle high consistently, so the distributor can find them easily later on. All happens while the STW remains on the chain conveyor, moving to the buffer. 5 printing stations are used, one at each chain conveyor supplying a buffer.

### B.1.2. Buffer Sorting

Just after the order tickets have been added to the STW it reaches the buffer. Here it passes over another RFID antenna used for the buffer sorting process (07). At this moment also a time stamp is added to the STW noted at the 'BUFIN'. The buffer contains 12-15 tracks, each dedicated to specific types of STW. The type of STW is determined by the amount of product varieties on the STW, the amount of transactions on an STW and the destination of the STW. In table B.1 the possibilities are indicated but in practice only three distinctions are used. The 'simple trolleys' only contain a single product variety and have to go through the central distribution area. The 'Trolleys for location South' are only single buy STW to be delivered by the shuttle. These get a separate buffer track and are brought in bulk to a shuttle station. Finally the 'Complex trolleys', consisting of multiple product varieties (often differences in length or color). This is done as complex trolleys or STW require more attention and therefore have to be processed by the more experienced distributors. STW with an error are added to the complex trolley as these also requires special action.

The buffer floor is slightly tilted so that STW coming in from the chain conveyor roll towards the front automatically. This creates a FiFo organization within each track. At the front of the buffer lights hang above each track. These are used to indicate the type of STW place on the track, and also priority of certain tracks over other tracks. Table B.2 shows the possible light configuration. When the light burns green or orange it can also set to flickering. This is done when trolleys in those lanes are close to or over there scheduled time to leave the buffer.

Table B.1: Sorting types and groups

<b>Simple trolleys</b>	Simple, multiple transactions 4+
	Simple, 2 transactions
	Simple, 3 transactions
	Single buy (Area 1)
	Single buy (Area 2)
	"Doordraai" (not sold)
<b>Trolleys for location South</b>	Single buy, South
	Single buy, OZ (client)
<b>Complex Trolleys</b>	Complex (multiple product types), multiple transactions
	Error

Table B.2: Buffer light colors explained

Color	Meaning
Red	Do not take
Orange	Difficult trolley, available
Green	Simple trolley, available
White	One-buy trolley lane

### B.1.3. Distribution

The distribution takes care of the first sorting of the products by accumulating products for the same buyer on a specific location in the distribution area. This location is indicated by a path number and a position number in the path. The paths are numbered 1 to 50 with all the even numbers on one side of the area, and the odd number on the other side (figure 2.2). Within each path the positions are numbered counter clockwise, in the drive direction, as is illustrated in figure B.3. Due to construction features of the building or other reasons some of the positions can not be used in particular paths. On the right side in the picture some horizontal line are shown indicating the tracks for the second sorting process. Besides this numbering the positions also all have an unique number called the 'VDN' ('Verdeel nummer') ranging from 1 to 750 for the positions in the odd paths and 751 to 1500 for the rest.

A distributor arriving at the buffer selects a STW and connects its tracker to it. With his personal scanner he scans the STW ID barcode, or an order ticket. This starts the 'Voice' instruction and a time stamp is added to the STW noted as 'BUF'. 'Voice' is a system that that uses a computer programmed dialogue to communicate with the user, in this case the distributor. The system consist of a wireless communication unit and battery, a headset and a scanner. Also a personal voice profile is required of the workers voice. The system uses a dialogue to instruct the distributor on what to do next. The distributor has to confirm finishing the task by saying 'oké' or in some specific cases a number.

The Voice system gives the distributor a path number to go to, and when arrival is confirmed the position number is given. The position numbers are shown on the ground in

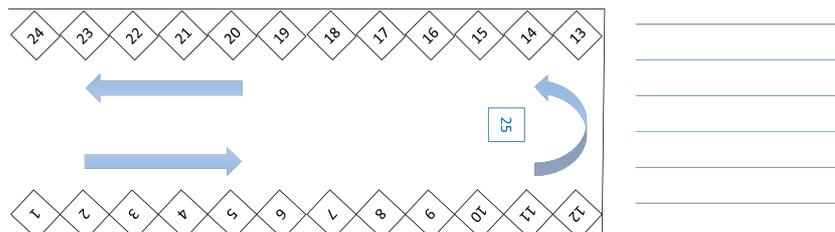


Figure B.3: Standardized layout of each path

combination with an additional two digit number. The distributor calls out this number and voice uses this to verify the distributor is in the right position. The distributor now check whether the transaction will fit onto the STW or that it full. If full, he will change the STW for an empty one, handing the full one over the the path manager. The empty one now has to be linked to the path position which is done by scanning the STW ID. If the STW is not full this is not required, but voice will ask the last for digits from the STW ID to verify the STW is linked to the right client.

If all is set Voice tells the distributor how much buckets to transfer, and in case of a complex STW also from which product variety. The right amount is transfered by the distributor and in the data base the transaction is linked to the particular buyer STW (08). Now Voice gives the number on the order ticket for this transactions and the distributor takes the corresponding ticket. To verify he has the right one a control number on the ticket must be called out. If correct the ticket is stuck onto one of the buckets. At this time also the 'CTFS' time stamp is made (10) and the distributor lets Voice know the task is finished. If there are transactions left on the STW Voice will continue with the next task. Otherwise the distributor goes to the closest buffer to get a new STW, unless indicated otherwise on screens in the distribution area.

It the last transaction is large enough or the STW contains only one transaction it will be dropped off with the STW at the location indicated as 25 in figure B.3. The distributor stops at this location and gets off the tracker. The order ticket is stuck on the frame of the STW and the distributor hands it over to the path manager or places it in the right track himself. During this research this position is indicated with a 25 to use it in the modeling; this is not the case in the real operation as does not have a position number.

#### **B.1.4. Path Manager**

Path managers have the role to sort filled buyer STWs on client address. The tracks adjacent to the path are assigned to one or more clients and used to accumulate their filled STW. The path manager will scan the STW using his hand held scanner before placing them in a track. The scan creates a time stamp 'WIS' and notifies a completed STW. Now all the transactions on the STW are linked to the STW ID in the database, the so called 'KoWaDi'.

The path manager is also on the lookout for transactions that are close to the scheduled time to start the delivery. The scheduled time to be forwarded is given on the order ticket. The path manager also gets a signal on its hand held when there is a transaction in the path that over this time already. The path manager will forward these transactions even when the STW is not filled completely.

#### **B.1.5. Delivery**

Several paths are connected to shuttle stations. In those cases the filled STW are placed directly in the shuttle queue and no sorting is required, and one of the order tickets is stuck on the frame on the right sight around shoulder hight so that the barcode with the address can be scanned by the machine. Past this point the delivery is automated. As the order ticket is scanned a time stamp is given to the STW and its transactions noted as the 'SSP'. This indicates the start of the delivery (11) and a signal is send to the client notifying the products are on their way. Further on along the route the STW RFID tag is picked up. This creates a final delivery time stamp 'AFL' (12).

In the other cases the LDK drivers pick up the STW from the second sorting buffer. He selects the ones to deliver first by reading the s time on the order ticket and selecting the most urgent ones. He will take all STW on a track as these go to the same client, and tries to combine these with other STW with nearby destinations. The destination is also noted on the order ticket, but the drivers often know by hard which tracks belong to which client area's.

The STW to deliver are scanned, creating a time stamp 'SSP', and combines them into long trains of 20 max. The scan also triggers a signal to the client to notify products are on their way (11). Scanning all these STW creates a list of STW on his hand held. On delivery the driver has to mark each STW on the hand held creating a final time stamp 'AFL' (12). However, in practice it is often seen that the driver does this as soon as the start driving, creating minutes difference with the actual delivery time.