MASTER

Modeling and improving the return department at Hollander Barendrecht

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Modeling and improving the return department at Hollander Barendrecht

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Abstract

In this report we analyze the results of the thesis performed at Hollander Barendrecht over the past six months. The main focus of Hollanders returns department is sorting crates that are returned after the deliveries to the supermarkets have been made. The returns department is in need of improvements on the cost-effectiveness and the capacity side of their work. The objective of this thesis is to create a model that can analyze the current situation as well as situations with improvement efforts. This was achieved by building a model in Simio - an object-oriented simulation program – that covers the part of the department within which improvements are presented. Data from Hollanders databases was combined with empirical data from the working floor in order to model everything as close to reality as possible.

Using the model we were able to present the results of four different improvement efforts differing between changing speeds of conveyors in the system to redesigning the work method. From these four improvement efforts two have shown results that would warrant implementation quickly, and at the time of writing one of those has already been implemented. Using the KPI of number of crates sorted we have already seen an 9% increase in throughput per working hour, with the implementation of the second idea possibly raising this increase to over 20%.

Contents

1. Introduction

This report presents the conclusion of the project performed at Hollander Barendrecht in their returns department to answer the question "*How can the effectiveness of improvements to the returns department be examined, and what can be done to increase the capacity and cost-effectiveness of the returns department".* To create a clear overview of the situation at hand, this introduction will first introduce Hollander Barendrecht and the returns department, as well as give an overview of the context of the problem at hand.

1.1 Hollander Barendrecht

Hollander, located in Barendrecht, is a logistics company focused on transport and distribution in the Netherlands. Hollander is the main supplier of all perishable and other fresh goods to the Plus Retail supermarket chain in the Netherlands. Their main business consists of inbound logistics, warehousing the stock, order picking, and performing outbound logistics on a daily basis for over 250 Plus supermarkets spread all over the Netherlands. The daily routine consists of order picking during the early night hours after which the products are loaded into trucks that head for the different stores. During the afternoon manufacturers with new deliveries start pouring in to resupply the stock that has been spent and the warehouse floor is resupplied.

Hollander started in 1929 as a small company selling fruit and vegetables in Rotterdam and has over time grown out to a large supplier in the retail channel. When in 1997 all large auction houses merged, the company The Greenery was created as a main trade channel for all fresh products. Since that moment in 1997 Hollander went on as a subsidiary for The Greenery, which is controlled by the growers of the products that are sold. Hollander has been working with the Plus supermarkets since 1993 and became the main supplier in 2003.

The initiative for this thesis for Hollander was to be able to better analyze what was happening in the returns department and to tackle problems the facility was having, since the current results of the department were below the levels Hollander wanted to achieve. In the recent past the returns department was outside the scope of Hollander and the work was performed under the name of The Greenery. About half a year before the start of this project a deal was made that would give control of the department to Hollander. So from the perspective of Hollander until now no large projects were run to improve the results.

Current problems within the returns department are that the costs to run the facility are higher than the allocated costs, as well as the fact that the facility has no room for growth in case demand increases or new clients are added. The facility is often physically full in the morning before the first shift arrives. Hollander is thus looking for methods to either increase the throughput or lower the costs of the facility.

1.2 Problem Context

To solve these problems without interrupting the day-to-day work in the department Hollander would need a way to asses new strategies or improvements theoretically. To achieve this a model would have to be created that would fit the inner workings of the facility, while being able to compare the current and new situations with different changes.

The creation of this model and the solving of the problems of cost-effectiveness and capacity as detailed above thus motivated the start of this project and thesis. The returns department is functionally separated from the rest of the work at Hollander, and an overview of what the department does can be found in chapter 1.3 while the way this department works can be found in chapter 1.4. After that chapter 2 will be present the exact research questions and problem definition.

1.3 Returns department

Until recently the Greenery has been responsible for handling all reusable shipping materials but has now given that responsibility to Hollander. The returns department is located in a separate warehouse close to the Distribution Centre (DC). Most of the fresh produce delivered by Hollander is supplied in crates that are stacked onto a Rolling Container referred to simply as a container. After produce arrives to the supermarket and has been shelved the empty crates are put on the container again and returned to Hollander with the next delivery. The returning trucks visit the returns department to offload all their containers and all the contents are handled in that facility.

Most of the work in the returns department is done manually with a team of temp workers and a smaller team of core employees that take care of day-to-day management. Every week over hundreds of thousands of crates are sorted and sent back to storage or to manufacturers to be filled with goods again. Empty rolling containers are sent back to the main DC so they can be filled up again with new deliveries.

The crates that are used in the process are those as supplied by Centraal Bureau Levensmiddelenhandel (CBL) and the Euro Pool System (EPS), while the roll containers are part of Hollanders own fleet.

1.4 Current work method

To better understand what happens in the returns department an abstract floor plan can be seen in figure 1-1 with detailed steps on what happens in the process. The numbers in the floor plan correspond to different steps of the process which will be detailed below. Step 1 is the arrival of trucks to the hall in which the returns department is contained. The trucks contain empty load bearers such as containers filled with empty crates. They are unloaded into the hall for further handling. Step 2 divides the containers filled with crates (about 70%) and the containers and other items that do not need further processing. The containers with crates are put in a queue at step 3 while the empty containers are moves to storage in step (7) where they will be sent back to the distribution center later.

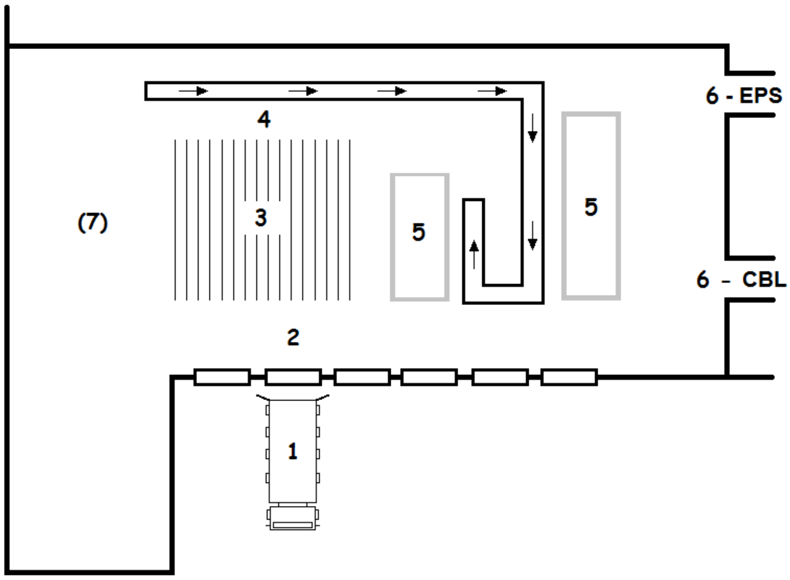

Figure 1-1 Layout of the sorting facility

In step 4 the crates are unloaded from the containers onto a conveyor belt. They are stacked per type of crate, which allows for quicker sorting later. Containers that become empty are sent to the same lot (7) where the empty containers from step two 2 are stored. The crates then follow a conveyor belt and pass a machine that takes pictures of the crates to count them. After this step 5 consists of again unloading the crates of the same type from the belt onto pallets. The conveyer passes from type to type and an employee focused on one type takes off all the crates of the correct type.

Step 6 is performed when the full pallets are now moved towards their final locations by forklifts. There are two types of crates, either part of the CBL or the EPS networks, which both have a different destination. The EPS crates are sent next door to the washing machine while the CBL crates are sent to a location for further storage. This is the final step for the crates and they leave the scope of the project here.

The final step (7) is performed sporadically and consists of sending all the containers that are stored back to the order picking center of Hollander, so they can be filled with full crates again. This is thus however not a continuous process, while the other six steps are.

2. Problem Definition

2. 1 Problem Definition

As noted in the problem context in chapter one there are some problems surrounding the returns department of Hollander. First of all the facility has proven to cost more per crate serviced than planned and budgeted when the facility was taken over. To get the facility back in to the green, efforts will need to be made to increase the cost-effectiveness – meaning more work gets performed per euro that gets spend. The second issue seen within the facility is the fact that there is currently almost no room available for growth, while the sales from the main DC and thus the demand for the returns facility keeps growing. When the shift starts in the morning, the buffer for containers is often completely filled to capacity.

Coupled with these main issues is the fact that there is not a lot of data available to make management decisions on. Some knowledge is available by request, such as the number of trucks arriving or the number of crates sorted, but there is no easy way to manage the data. This makes it difficult to decide on new long-term improvement opportunities, since their impact cannot be measured.

For these reasons the problem definition is stated as follows:

There is no method available to test improvement opportunities, while there is a need to improve the cost-effectiveness and the capacity of the returns department.

From this problem definition we can now formulate a research question and the sub-questions that will be further answered in this thesis.

2. 2 Research Questions

As described in the problem statement the research question will focus on improvements and how to test those improvements. For this reason the research question is formulated as:

How can the effectiveness of improvements to the returns department be examined and what can be done to increase the capacity and cost-effectiveness of the returns department?

The question already clearly shows the sub-questions that need to be answered in order to fully answer the main research question:

1) How can we test proposals for improvement without disturbing day-to-day work?
2) What methods can Hollander employ to improve the cost-effectiveness of the returns department?
3) What actions can Hollander take to allow for growth in the returns department?

The first sub-question has a main purpose of allowing further research to be performed easily. It allows for a better understanding of the work currently performed and gives the possibility to analyze what is happening on the working floor. When improvement are then presented the answer to this research question will allow for easy comparisons with the current situation.

In the second two research questions such improvements will be identified from the working floor and the analysis from the first question. These questions aim for new ideas to be introduced to the working floor to allow the main problem to be addressed.

2.3 Scope

Hollander is a large company with many different departments and types of work performed. For this reason a scope is set for this project to limit it to the parts that need improvement in this project.

Most foremost the sorting facility is only a small part of the daily work effort performed at Hollander. It is important that the working of the sorting facility does not impact work in other departments. As an example, there are empty containers supplied to the main warehouse from the sorting facility, which are needed for the day-to -day work. These containers are needed at certain times, but we limit ourselves to not changing this schedule.

A second scope is put on the size of these improvements. After completion of the research Hollander will have four more years remaining on their contract with the Greenery. To stop improvement ideas from going out of the control of that timespan the limit is set that the facility should remain within its current location. Growth patterns should be handled through higher efficiency and capacity, not by building a new building with more space.

A last part of the scope is set on the level of detail in solutions. While workers can be micromanaged in their work, e.g. what crate they are stacking at which hour, this is not the solution that is sought for. Changes in planning or work types should be kept global, as the entire team is working as a single force with a given number of people per day. As is now, everyone comes and leaves at roughly the same time as their coworkers with the same job.

3. Data collection

In order to create a realistic model of the department we need to understand what happens inside. There are three main aspects of information that are needed in order to get at least a basic grip of what is happening. The first aspect is the demand for the model, which in this case is measured in trucks arriving and the contents of these trucks. The second aspect is how every piece if handled in order to 'complete' the demand. The last aspect is how to measure our system in order to later know when improvements are made or when a new solution is unfeasible.

3.1 Demand

In a traditional sense demand is what we measure when we want to find out how many 'customers', or in this case crates, are to be processed by the model. The demand on the model is here determined by the arrival of trucks with containers, which each have their own distributions. Before trying to figure out the distributions with which these arrive it is important to note that the customers are crates, not people, so they will not decide not to queue up or to leave.

Trucks

In order to find data on the trucks the GPS data they send out can be used. The trucks send a signal when they arrive at a destination which is then logged by the transport department. This data has a few problems, the main one being the fact that trucks also arrive not to deliver crates but to pick up the empty rolling containers as detailed in step 7 in Chapter 1.4. Another problem is that trucks that hang out for a longer time might get logged several times in a row. A full detail of the arrival times can be created when these inaccuracies are filtered out. To not reveal all company details on truck movements and the like the Figure below has been detailed as percentages of daily arrivals.

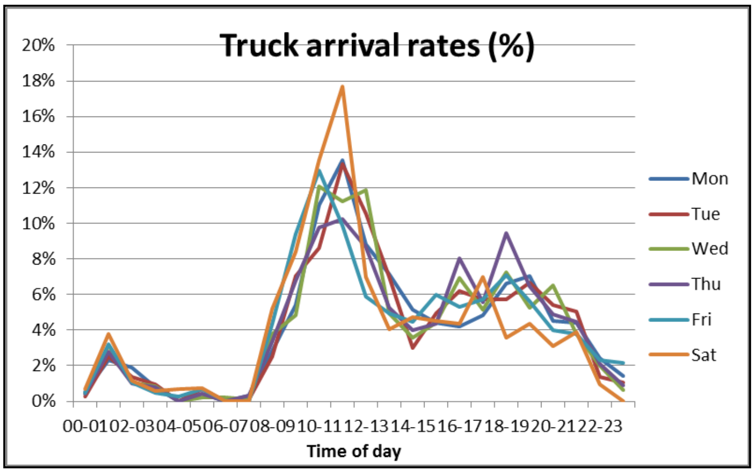

Figure 3-1 Arrival Rates of trucks to the facility

Notable is thus the fact that arrival rates vary greatly over the course of a day. The arrivals times are not set in stone and depend on routes, traffic, delays, and other outside factors. To use these arrival rates in the model we need a corresponding distribution to fit them to. Highlighted below will be the test for all the timeframes that averaged to 12 arrivals.

The first idea was to try to fit the arrival rate to the Poisson distribution. Below the outcomes are when comparing the histogram of the arrivals over these periods to what the Poisson distribution would give with an expected value of 12, the sample mean. There are a total of 78 occurrences.

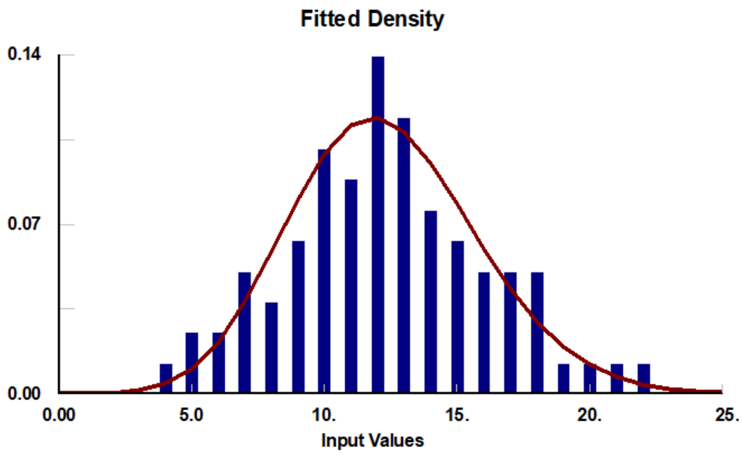

Figure 3-2 Distribution of arrivals against a plotted Poisson with mean 12

The histogram looks to fit our Poisson distribution quite well, but to test the hypothesis that the fit is correct, the Chi-square test was performed on the data. With the help of Statfit we can determine that the best Poisson fit here is separated into 11 intervals with a total chi-square value of 3,65. We compare this to the p-value table on 10 (= 11 – 1) degrees of freedom to find a p-value of over 0,95 for chi-square scores under 3,94. The exact p-value is 0,962 and thus we have no reason to reject the Poisson distribution for our arrival rates.

Containers & Crates

A truck arriving to the facility is one part of the arrivals but it might even be more important what goods that truck is carrying. Since servers work mainly with crates and not with trucks we need to find a calculation that tells us how much work each truck delivers. The contents of a truck differ greatly from truck to truck so for this calculation we used a large population of older deliveries. From the internal data we could find sample data how much crates and load bearers each truck has delivered in the past. It did however not show how many of those containers arrive empty and thus do not contribute to our buffer (step 3 in chapter 1.4) and that ratio is important to know.

From the physical paper cargo manifests in the archive the conclusion could be made that about 70% of the containers arrive to the department while carrying crates. This information can then be used to analyze the arrivals in each truck. After analyzing over 5000 truckloads per day of the week we have a clear overview of what arrives in each truck.

From the basic data we can find an average number of crates and containers each truck is carrying per day. Again using Statfit we found out that a normal distribution would not fit to our data so we had to find a distribution that fit the data better. For both the crates and the containers a Beta distribution with a lower bound of 0 was chosen.

For this data only different days of the week were taken into account, which showed differences of up to 30% between Sundays and Fridays, while non-weekend days remained closer with only up to 20% difference.

3.2 Workplace

The work performed in the department is done at a certain speed where each movement takes a certain amount of time. The amount of time each action takes to perform has been noted by empirical measures when walking around the department with stopwatch functions. This goes for mechanical operations such as the speeds of the conveyor belts to the amount of time it takes to unload all containers from a truck.

Crate specifics

A more difficult subject is the time it takes to empty a full container on the conveyor belt. To save time and effort each crate is not just placed on the conveyor belt but also stacked with other crates to create a vertical stack of crates with a certain height limit (see figure 3-3). Since each crate has a different size and the workers try to only stack crates of a certain type we need to work out how large these stacks become per different type. Since we don't know the contents of every different container an approximation would be made in how many stacks the container can be offloaded onto the belt. For this we can use the average amount of crates on a container and the average number of crates in a stack on the conveyor belt.

Figure 3-3 Stacks of crates on the conveyor belt

This data was created by observing the stack size (SS) of each different type of crate. The distribution between different types of crates can be found in the year reports of the amount of crates that have been handled. A percentage scale of different crates and their prevalence has been created. By combining these two pieces of information we can determine how many stacks exists of each type and size and thus how quickly a container can be emptied.

Because of the larger stack sizes - since the crates are foldable - , EPS crates take up about 30% of the crates counted in total, but only 20% of the stacks that pass the counting machine on the conveyor belt. An opposite example is the Type D crate, which is 11% of total crates but amounts to 23% of all stacks passing the conveyors. The weighted average stack size was calculated at 14 crates per stack.

Name	**Type**	**Crate % (2017)**	**Stack Size**	**Stack % (2017)**
CBL Type A	Rigid	1%	3	**4%**
CBL Type B	Rigid	1%	5	**3%**
CBL Type C	Rigid	0%	5	**1%**
CBL Type D	Rigid	11%	5	**23%**
CBL Type E	Rigid	28%	12	**25%**
CBL Type F	Rigid	27%	12	**25%**
EPS Type G	Fold	7%	15	**5%**
EPS Type H	Fold	3%	15	**2%**
EPS Type I	Fold	4%	15	**3%**
EPS Type J	Fold	7%	15	**5%**
EPS Type K	Fold	3%	15	**2%**
EPS Type L	Fold	5%	15	**3%**

Table 3-1 Prevalence of different types of crates

Worker specifics

The working hours are another interesting subject for the facility. There are guidelines to the work hours, such as Mondays always start at 06:00 and finish around 15:00, but those end times are not fixed. In general, the crew works from early morning and continues until the queue is empty before they head home. All other information on the amount of people working during each shift is also available from the schedules.

A more difficult item to measure is handling speeds. There are two moments when the crates themselves are directly handled by a worker. The first is when the crate is lifted onto the conveyor belt and the second is while the crates are taken from the conveyor again. In the first situation the task is performed by a group of people who also perform other duties such as bringing in new containers and removing the empty containers. Oftentimes they also do not just simply make an effort to place items on an empty spot in the conveyor but they also stack their crates with the crates of a colleague. Individuals varied too much to create an effective measurement per person so in order to have useable data we decided to combine their efforts together to create a stacking rate for the whole team. The stacking rate is measured by the amount of time it takes to create a full stack on the conveyor. We also quickly found out that the workers can create stacks faster than the conveyor can handle which means the top speeds are not entirely reliable.

The speed that workers can take crates from the conveyor is also difficult to model. Since each worker is only responsible for claiming a single type of crate, the workload is determined by random arrivals with large downtimes. To still have data we measured the average time that elapses while a worker is handing a stack. We however do not know whether these times are still valid when more workload would be present. It was however seen that at the current moment, workload was lower for workers on EPS crates than workers on CBL crates when measured in actions per timespan.

3.3 KPI’s

The Key Performance Indicators (KPI’s) are the measurements the company uses to determine the effectiveness of the department and are thus also the measurements used in this thesis to compare solutions to each other and the current situation.

The main measurements used by Hollander are the ‘Performance’ and the ‘Sorting Performance’. Both are measured daily and have a norm that they are compared to. Both Performance and Sorting Performance are closely related with a slight difference.

Performance is measured by the amount of crates the department handles in a day divided by the amount of hours all employees make on the working floor, including people who unload trucks at the docks and forklift drivers.

Sorting Performance is calculated by the amount of crates handled in the day but divided by the hours worked only by the employees working on sorting. This means it only counts the actual hours worked by the workers placing crates on the conveyors and offloading them again instead of the entire 24 hour operation.

A third measure added for the purpose of testing new situations is the maximum amount of containers in the queues. At current Hollander does not measure this information, but since space to store containers is limited there is an amount that cannot be exceeded without building a new facility.

3.4 Conclusions

Most of the information that is required to build a model is either available without much trouble or has been calculated from historical data and fit to a distribution. The main problems with modeling that could be encountered in this project would be the fact that arrival of trucks varies with time and the fact that the workers do not have exact working times that a model could work with. These are important factors in deciding on a certain model that would fit the situation and this will further be discussed in the next chapter.

From the data we can also pull some conclusions on possible bottlenecks. The fact that workers can stack crates faster than they are being pulled away by the conveyor is a clear sign of a possible bottleneck. This was confirmed by the other side of the conveyor where we noticed that workers spent quite some time not working while waiting for crates of the correct type, with an even lower utilization when they were working on EPS crates. This signals that the conveyor belt is a possible bottleneck which can be researched as an improvement effort, as well as the fact that the EPS sorting side might need in increase in workload to be at full effectiveness.

4. Creating a model

4.1 Design Requirements

To answer the first sub-question a way has to be found to analyze the effects of improvements to the facility. This can be done in several different ways of which the easiest is probably an approximation or a simulation of what is happening in the facility.

The facility as shown earlier can be approximated as a large queueing system. In this queueing system the 'customers' are the containers as they are brought in on the trucks. As soon as they enter the facility they are put into a queue waiting to be unloaded onto the conveyor belt. From there on the conveyor belt can be seen as a separate system that is manipulated by the workers on the other end. In order to find a model that can fit to this system certain requirements must be met.

For the model required for this project the main design requirements are:

1. 24 hour operation modeling

The facility is running the entire day without a break period. While during some hours not many returns are scheduled the facility never truly closes. This means the model must allow for continuous processes without exact start and ending moments.

2. Multiple day modeling

Arrivals and working hours differ from day to day. For this reason the model will need to be able to handle different days with different setups. Most importantly it must be able to check effects on consecutive days with for example no work being performed on Sundays and thus extra workload on Monday morning.

3. Allowing for non-homogenous arrivals

Trucks arrive in a pattern that changes continuously. In many queueing models it is assumed that arrivals are a constant factor as described by e.g. a Poisson distribution. In the case at hand that assumption cannot be made since the rate of arrivals changes every hour. This can also be called as a non-homogeneous arrival pattern and the spread can be found in the previous chapter on data.

4. Allowing for flexible working hours

Every morning at six the daily sorting workforce arrives to the facility. This would of course be easy to model. The big problem here is that they do not leave at a set time but instead keep working until the buffer is empty and the sign is given that they can go home. This means that the processing rate of crates also varies between days and that a trigger is needed to stop work for the specific day.

5. Easy to understand

After this project is finished the model remains in the company, so new suggestions for the facility can be tested. This means it should either be easy to understand or someone already should have experience with such a model.

4.2 Modeling Method

On first thought a basic queueing model would be a good approach to start the search for a compatible model. However a basic M/M/1/k queue does not fit the requirements as specified above. Specific alterations can be made to such a model in order to try to fit it to our requirements. Possible adaptations are those of Vacation Modeling (VM) to model time off work and making the queue fit a Varying Time Arrival (VTA) system. This subject has been further researched during a literature review on queueing models which has shown that at the current time no model fits together both VM and VTA properties while still being fit for the current purpose. Options for traditional queueing models included the ideas on VM as described in a M/G/1 queue by Ayyappan & Karpagam (2018) as well as the ideas of Fluid queueing - see Chen et al. (2011) - or backlog carryover approximation - see Stolletz (2008) – to create a VTA queue. However these systems were determined to be too tough to combine to a workable system within the timeframe of this project.

The second option is to make use of a coding language or a simulation in a visual program. In the past years Hollander has hired a professional modeling company to create a model of their main warehousing system using Simio. With the use of Simio for our model some people on site would already be able to work with the model without much more training. When looking at the other design requirements it turns out that Simio also fits requirements 1 through 4 as it allows for clear scheduling simulation over multiple days.

Simio is an object oriented simulation software package that allows for a working simulation without the need to use programming. Building blocks are used to create processes logically instead of large blocks of code. While programming code could be a benefit for easy implementation for harder steps the building block structure does allow for easy adaptation to the model when a new user wants to edit steps. An additional benefit to using Simio is that it gives an actual visual on what is happening within the facility. This could benefit when analyzing the inner working of the facility and seeing the bottlenecks that new improvement efforts have appear on screen instead of just number being output.

The downside with the usage of Simio is that the only real source of information on how to use Simio is the main manual that comes with the product as well as the fact that it is a niche product which means there is not a lot of documentation available online. Besides that the model of the warehouse build by the modeling company could be looked at for help with starting a new model in Simio but it did not share many of the requirements that the current project has. After internal discussion it was agreed upon that the downsides were manageable and that Simio would be effective at modeling with our design requirements in mind.

4.3 Processes

With the modeling method decided on the next step is to decide how each of the steps in our process fits into the Simio model. For this reason the steps as first described in section 1.4 are pulled up again and are fitted to one of Simio's building blocks. First an overview of building blocks will be given with basic ideas behind what actions they perform. Second we will match each step of the process with one or more building blocks to recreate the entire basic sequence.

The first process is that of trucks arriving and being unloaded. For this process we can create a truck that is spawned from a *source* according to the arrival data. The truck follows a path towards the *separator* where the truck (parent object) is processed and then released while containers (child objects) are created. After the time it on average takes to unload a truck the containers are released to the working floor for workers to bring them to the correct next step. Empty containers are brought straight to the empty storage to keep track of their numbers and then the *sink* while full containers are brought on to the next *separator*.

Name	Function (Pegden, 2009)
Source	Creates new objects into the simulation
Sink	Destroys objects that finish the simulation
Server	Takes one object and releases it again after a certain time period
Separator	Takes one object and creates two objects from it after a time period
Worker	Carries objects bringing them to different building blocks
Paths	Allows an worker to travel over it at a certain speed (with or without object)
Conveyor	Functions as a path traveling at a set speed without needing a worker present

Table 4-1 Simio building blocks explained

Step	Minimum building blocks
Truck arrival and unloading	Source (trucks), Separator (trucks & containers), Paths, Workers
Emptying the containers	Separator (Containers & Crates), Workers, Paths
Riding the conveyor	Conveyors of different speeds
Sorting the crates	Workers, Paths
Leaving the system	Sink (Crates), Sink (Containers), Sink (Trucks)

Table 4-2 The project processes combined with the building blocks

In the next process the full containers are waiting in front of a *separator*. When the shift begins this *separator* creates multiple stacks of crates from each container. The empty containers are once again brought to the empty storage, followed by the *sink,* while the workers start loading the stacks of crates onto conveyors.

Next up is the process that simply consists of the crates riding conveyors until they are picked up. These conveyors are placed in series but there are some differences in speed and type between the conveyors. One of the conveyors uses cell spacing, i.e. exact locations where crates can stand, while other conveyors are moving freely and the crates can occupy any spot on the belt.

The sorting process is attached at different locations to the conveyor belts. Every different type of crate is collected at a different location of the conveyor belt. Workers are available to collect crates of the type they need and move them to the next step. Each worker is thus assigned to a certain section of the conveyor belt.

The last part of the process is simply the crates and empty containers leaving the system. Crates simply get moved to *sinks* so the leave the system. *Sinks* are also available for the containers that have been emptied and the trucks.

4.4 Modeling details

When the basic idea behind the model is complete true modeling can start. Below snapshots from the model in progress are displayed. The final model is an expansion from the first basic processes and additions will be explained per part of the process.

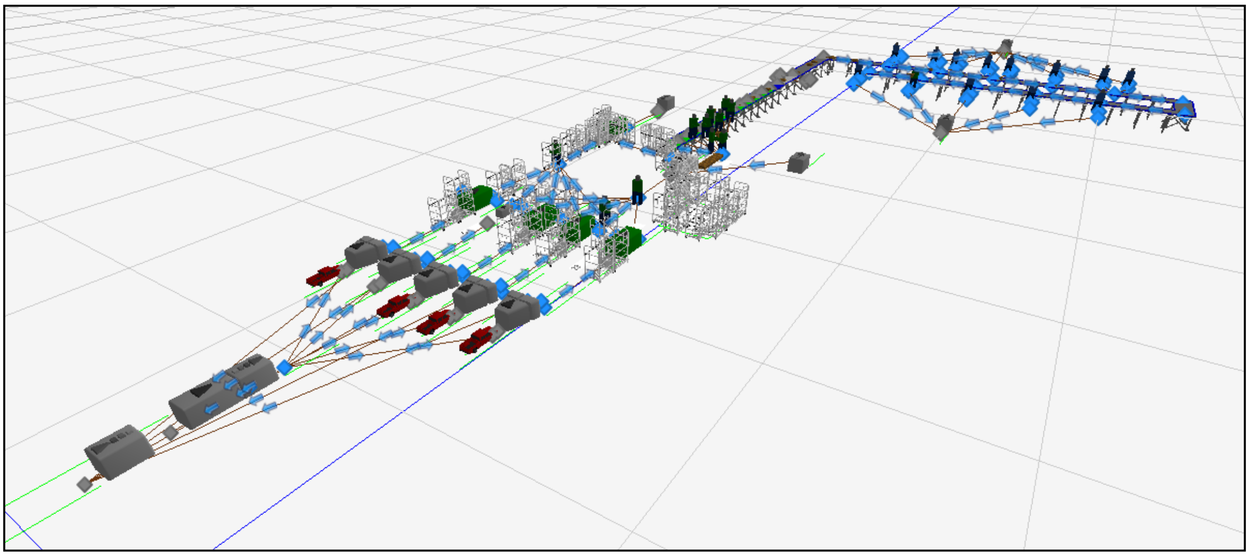

Figure 4-1 Full overview of the model

In the first process step with trucks arriving several new additions have been made. First of all an overflow system with a new queue has been put into place for when trucks arrive without an open dock to unload their holdings. Besides that a new *server* has been realized on each dock to release containers slowly while the truck is being emptied instead of dumping all containers at once.

These changes can be seen in Figure 4-2 where the first section of the model can be found. To easily identify what is happening the vertical lines will be used as navigation. The image is split in 4 large vertical sections and a small bit on the right with extra additions.

In the first vertical section three machines can be seen. Those are (in order) a sink to destroy trucks, a server to keep trucks busy if they need to queue and a source for trucks. The second section contains the earlier mentioned five separators that output the truck back to the sink and continues the containers instantly to the next server. The five servers in the third section control the speed of unloading so that a small amount of containers come out of the truck at a time. The containers are put on pick up points depending on whether they are full or empty. Empty containers get moved to a server in the top of the fifth section so that the amount of empty containers can be measured (500 in this image) before they are sent on to the main warehouse. Full containers arrive at the white separator to be further processed and another label shows the current size of the queue for full containers (313 in Figure 4-2). The source in the bottom right can create a one-off delivery of full containers at the start of simulation so that there is work available from the start.

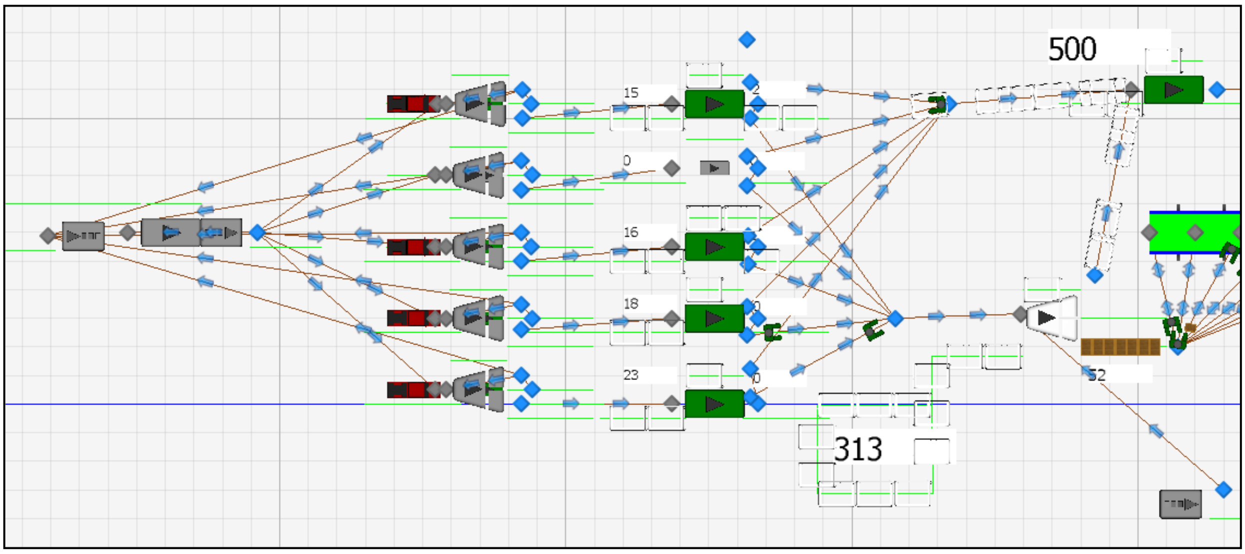

Figure 4-2 First Section of the model

In the second picture presented an overview of the second part of the processes can be found. If we follow the arrows from the top left of the image to the end of the loop we encounter the rest of the model along the road. First of all the back side of the separator can be seen. Here crates are picked up by workers and put on different sections of the conveyor belt. From here on they move past the different conveyor belts. Each color belt has a specific attribute to them. The light gray belt has the highest speed and uses cell spacing. The green belt is used for depositing crates onto the belt and the blue belt slightly speeds up in order to get to the cell spaced belt at a higher speed. The dark gray belt is a single system and has a speed slightly below the others.

On the dark grey part of the conveyor there are 10 connection points where workers can access the conveyor. Some parts handle crates that are more common so two workers can access that spot. The access points are split between the left and right part of the U-shape with five on each side. The right side of the conveyor is mainly used for crates of the CBL Type while the left side mainly holds the different types of EPS crates.

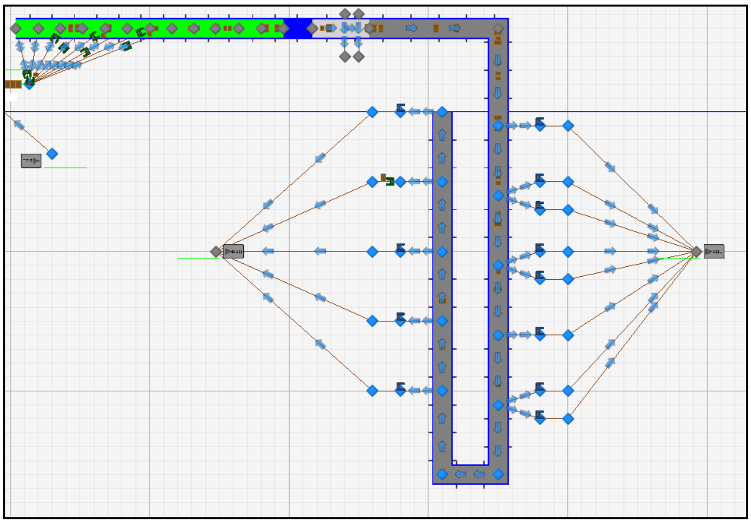

Figure 4-3 Second section of the model

4.5 Variable settings

In order to make effective use of the possibilities of simulation it is necessary to give input to several variables. In this section a quick description of the different variables can be found with an overview of what they are used for.

General Settings

In order to get accurate results from the simulation the settings around the simulation should be set carefully. A simulation often takes multiple runs before handing out results and the amount of runs made can change the range and confidence shown in the model. A test run was performed with the model in place to see the difference the program would give. Tests with 3 and 5 runs were quickly dismissed because the results would miss a large amount of the variation since they have too few data points. Setups with run amounts between 10 and 25 all gave a clear overview of all results that could be read out with confidence intervals that did not differ much between each of those options. The 25 run system gave confidence intervals for the mean of the result only 25% smaller and the results of the mean only shifted by 1% compared to the 10 run system. The time to compute was however also much larger with many scenarios being run. To thus save on computing time all tests will first be performed with 10 runs. If results are very close more runs can be performed.

Another important setting is the warmup period of the model. A warmup allows the model to delete results after some time of running to allow the model to get into a more steady-state. For most of our tests a one-day warmup period is satisfactory since the model is empty every day in the afternoon again. The first day however not enough arrivals take place to work at full capacity so this day is kept out of the results.

Speeds, Times and Ratios

Every piece of the model has a standard value for the amount of time it takes to perform a certain task. In order to create a model that runs like the real situation all these times need to be adapted to their corresponding counterparts. A lot of the information needed for this was already done as part of the data collection. The following parts have a certain setting for their time or speed:

Paths either are based on time needed to move or length of the path. Most of the paths in the model are based around time because the speed of different workers is not different, making it easier to adapt if certain movements are changed. Every single path in the model thus has received a time varying from 0 (instant movement, e.g. between the truck separator and the server giving out the containers) to the time it takes to actually make the movement in the facility. *Conveyors* on the other hand have a set speed in which the crates pass over them. This speed is measured in meters per second and is a variable that can be changed in their configuration.

Other parts often have a processing time set to them such as the time it takes to offload a truck or the time it takes put a single stack of crates onto the conveyor belt. In the cases where this is not variable the times are set directly into the machine while otherwise a global variable is created that can easily be changed.

As said in the data collection part, containers either arrive to the facility full or empty. The rate at which each of those options occurs is currently set, but might change in the future. In case anything changes to this information, it is possible to change the ratio between the amounts in order to have a model that is closer to reality.

Schedules

Schedules refer to the work schedules of different workers and machines on the working floor. There are schedules for different types of workers. In the model there is differentiation between three different types of workers: those working the docks, those filling the conveyors and those that take the crates from the conveyor again. While in the current situation the last two types follow the same schedule of sorting while the schedule for the dock workers is different. Since dock working is a 24 hour operation schedules run the entire day but have more workers available during the day than during the night.

The different machines are also working on schedules. The separator that creates crates will only perform the action during daily working times while the machines at the docks are in operation the entire day. These schedules can again easily be adapted if an improvement effort calls for the need.

Another variable setting tied to the schedule is the number of people that are working. Each of the different workers is part of a certain group that has a setting for the amount of people that start working at the model start. In case more people would be set up at any of the points where workers are used these settings can change their behavior. Important to note is that currently every worker in the sorting part of the system is connected to his or her own travel path, so when the amount of workers is changed it is important to also change the number of connections available for them to work on.

Tables

Tables are how we can import data from e.g. excel files into the Simio model. The current system has multiple tables available to it. One of the most important ones is the rate table which allows for the design requirement of time varying arrivals. In the rate table information is stored on the amount of arrivals in each hour of each day and the model will automatically randomly generate an average of that amount of arrivals in the hour in question according to the Poisson distribution.

The second type of table is used to for example determine the type of crates in the system. The ratio of different types of crates as seen in the data chapter is stored in the model. When a new crate is created by the system it runs an automatic process to determine the type that that specific stack of crates is. This information is later used to determine at which point of the conveyor a certain stack of crates needs to be picked up.

4.6 Analyzing improvements

In order for the model to actually fit the need of Hollander we need to be able to compare the results of the simulation between different settings or builds. Simio has a built in Experiment function that allows the model to run simulations for every variable that needs to be changed. If the experiment entails the changing of the lay-out or functions of the facility they can be build next to each other with variables detailing which machines are working in each simulation. The Experiment function then runs a set amount of simulations for every difference that is made and reports on the output of each simulation.

The output or response to each simulation can be any output from any of the machines or workers. Simio keeps track of almost all statistics that could be necessary and if a statistic is found that is not automatically captured it is possible to save it by other means.

For the purpose in this project the main results that will probably be used are thus the amount of crates handled as that is part of the main KPI that Hollander uses. The amount of hours worked can be easily determined as well in order to recreate their full KPI. The amount of crates handled can be easily calculated by checking the outputs that each of the sinks at the end of the conveyor system gives. Added together these amount to the amount of stacks that went through the system which we can then multiply by the average stack size.

Other important stats are those which are not currently measured but those of which we know there are practical limitations. The amount of space inside the building is not infinite and every full container should be stored within the buffer for processing. This means that it is important to know the size that this queue reaches in order to determine if the solution is feasible. For example if one would stretch out the working day with only half of the people working at each moment the same work might be performed in the same amount of hours but the queue size might become too large halfway through the day. Simio has a way to check this by asking each run the maximum size that the buffer has reached within each simulation. While it is averaged for quick analysis first the full results are still available in the final data package.

When checking other solutions new problems might come into play that do not occur yet. Imagine the same idea as mentioned earlier about spreading the working hours more over the day. If this idea were to be implemented at the docks trucks might linger around longer and create a wait before they can unload. The server that gives trucks rooms to wait can report on how many trucks had to wait before they could find a place to settle.

4.7 Conclusion & Limitations

Before the first improvement simulation was run several test were run to see whether the simulation achieved results that seemed close enough to continue with the model. After tweaking some of the variables to create a good average for the working times the simulation came to results that were close to what performance could be on a normal day. Since there is no exact data on arrival times, crate amounts and worked hours available for any day the visual part of the simulation was used to ascertain that the model gave a good idea on what a normal day might bring. We can thus start with testing improvement efforts on the model and determine that the first sub-question to our research question is answered.

We however also ran into some limitations that modeling or Simio have that may or may not be important in the future. Most importantly the working speed of humans is hard to predict when situations change. Simio thus only knows the working speeds in the current situation and when conditions change drastically new estimates might have to be made. A second problem is that Simio gave some difficulties with the conveyor belts. Instead of the crates that are to be placed waiting in line for a spot the model would sometimes simply push a stack of crates between two already placed stacks. Since the amount of crates that get handled does not increase with this problem the model can still be used.

5. Improvement Efforts

NB. Please note that in this chapter all numerical values are scaled to a round factor for the current situation. Improvements can thus be read in percentages.

With the model working the next step is finding ideas to test on the model and see whether they are effective or not. The start of this process was walking around on the working floor and trying to figure out where the bottleneck was. If a bottleneck can be found further ideas behind it can be theorized and worked out to a solution. The next step was asking employees and management about ideas they had that might work but that had not had room to be tested because they would make too much changes to the facility.

When going back to our research question two main problems were identified. The first problem was the cost-effectiveness which can easily be improved in the case where the throughput is raised as the main cost is man-hours. The second problem was capacity or growth. The problem with capacity was that some mornings all of the lanes that contained full containers were filled. In case a growth would take place there would be no more room for these containers. In the first section for improvement efforts the aim is to tackle the bottleneck for both of these problems.

Multiple improvement efforts have been looked at while four have made the cut to be tested in the simulation. The first two are ideas thought of while observing the working area, while the last two ideas were found in discussion with management. To better cover the cost of the system two ideas are presented. Managing the conveyor belt speeds to tackle their bottleneck is an effort to increase the throughput of the entire system. Another idea in this category is the third presented idea of changing the work method towards multiple timeframes in which a different type of crate is sorted. The main idea behind this is a lower amount of people needed in the backline for sorting and thus a decrease in hours made.

The other two ideas focus on creating a situation that allowed for more growth. While higher throughput allows for more crates to be handled in a day there is still a problem with the lack of physical space. The second idea presented is that of shifted working hours. The current working hours create a wave pattern where one day work is finished early forcing the next day to finish late. By changing the working hours we hope to break that pattern. The last idea presented here is that of the purchase of counting machines. This has been a management idea for some time in order to make it easy to handle the crates on the conveyors as well as allowing easier counting methods. This idea was requested to be run through the simulation and the results are presented here.

5.1 Conveyor belt speeds

On the subject of throughput it quickly became clear that the bottleneck was around the part where crates were put onto the conveyor and not where they were taking the crates of. Through the first observation it seemed that workers on that part of the conveyor simply did not have enough room to place down crates. As the conveyor moved on towards the next section more and more ‘holes’ would already be filled and towards the end of the line the workers had almost no room and could only stack a few crates on top of already made stacks. For easy understanding an overview of this belt area has been added below.

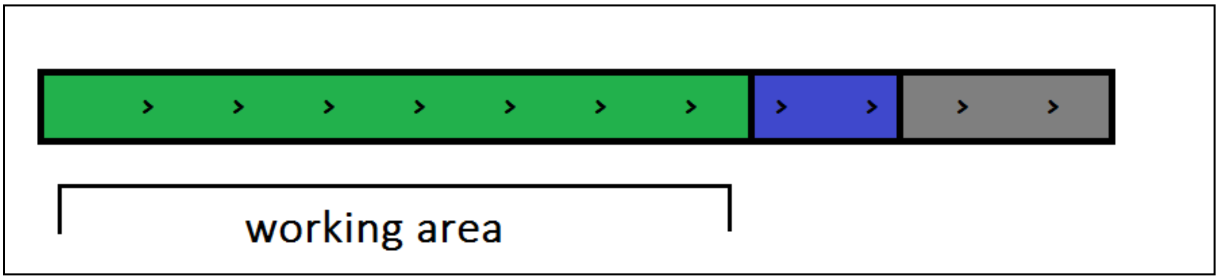

Figure 5-1 Schematic of the first part of the conveyor belts

All belt colors are true to their real-life counterpart in this image. The green belt is used for placing the crates down onto the belt. When it transfers to the blue belt, the belt picks up some speed before it is ultimately forwarded onto the grey belt that has the highest speed as well as being the only belt with cell spacing (set positions a crate can take). The cell spacing is used so that the counting computer can get accurate reads on when crates pass the camera. Between the blue and the grey belt a small gate is present to make sure crates align with the cell spacing.

One of the simulation tests performed was increasing the speed of the green and the blue belt to match up to the grey belt's cell spacing. The ratio for crate to room in a cell was different for the smaller and larger crates, but was estimated to be around 70% of the size of a cell being taken up by a crate. The belts were thus matched to 70% of the grey belt's speed. Here the first improvements could be noted. These simulations however sped up the green and blue belt to almost twice their original speed. Scaled to the speed of the grey belt of 1 m/s the green and blue belt originally had speeds of 0,37 m/s and 0,42 m/s. As such this solution was deemed not acceptable since it would prohibit safe working conditions and would create too much friction on the belts due to crates pushing each other at high speeds.

As a second option for the second simulation, the reverse was done. This time the simulation was run with the grey belt slowing down and the other belts at the original speeds. The graph found below shows the decreases in speed of the grey belt and the relative performance the output has. The most right data point thus sits at a speed of 1 m/s and a output of 100% for the baseline. In this graph it can clearly be seen that the earlier mentioned ratio plays an important part in optimizing the speeds for the conveyor as shown by the saw tooth shape the graph takes on. The high spikes of the tooth are the points where the ratio is hit perfectly and with a just slightly higher speed on the grey belt the prior system cannot keep up anymore and performance drastically drops. The originally calculated 70% ratio however turned out to be an incorrect ratio with 61% being a closer score. A possible explanation for this could be the movements of the gate slowing down the crates.

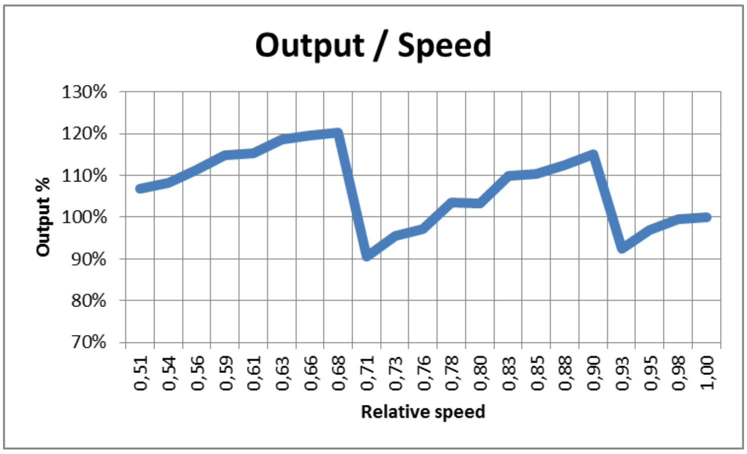

Figure 5-2 The amount of output each grey belt speed provides

For the next more detailed set of simulations a large matrix of possible speeds was created for the belt systems. In this simulation the green and blue belt were combined into one speed as the speed of the blue belt would make no difference if the crates came along faster from the green belt. For the first set, the green and blue belt, speeds were set to variations of their old speed but with slight increases in each iteration. The same happened for the grey belt but instead of turning its speed up the decision was made to try and speed that belt down. Because it was impossible to predict the speed of placing crates in the new situation the belt was simulated to be almost filled.

The final result from this last simulation had about the same optimal result as the previous set of results, about a 20% increase in throughput. It should however be noted again that this throughput would not be reached in practice since the conditions were optimal for the simulation. The final speed of the belts (scaled again to a speed of 1 for the old grey belt speed) was a speed of 0,55 for the combination of the green and blue belt and a speed of 0,9 to the grey belt, which is about the same ratio as the optimal result in the second simulation of 61%.

After discussion with the respective foremen on the two options it was decided that the simulation results of the third session would be implemented. The main reason was that a faster track at the front of the system would allow people more room to work and thus make the work easier to perform. Implementation however was a bit tougher than expected since the conveyors didn't measure in speed (m/s) but in rotations (hertz). This meant that getting an exact speed out of the conveyors would prove tricky. After testing many different options and measuring their speed an option was chosen with a speed of 0,51 for the starting section and 0,87 for the grey conveyor.

After first implementation results immediately improved in the days following. Below a chart can be found with the average results before and after the day the changes were made. Within the first month the KPI's increased by 7% scaled from the average prior to changes. Another analysis of the results two months later reported an increase of over 9% of the average before changes were made. As no other changes have been performed this can be attributed to the change of the belt speeds which means this effort has reduced about 9% of the hours worked in the facility.

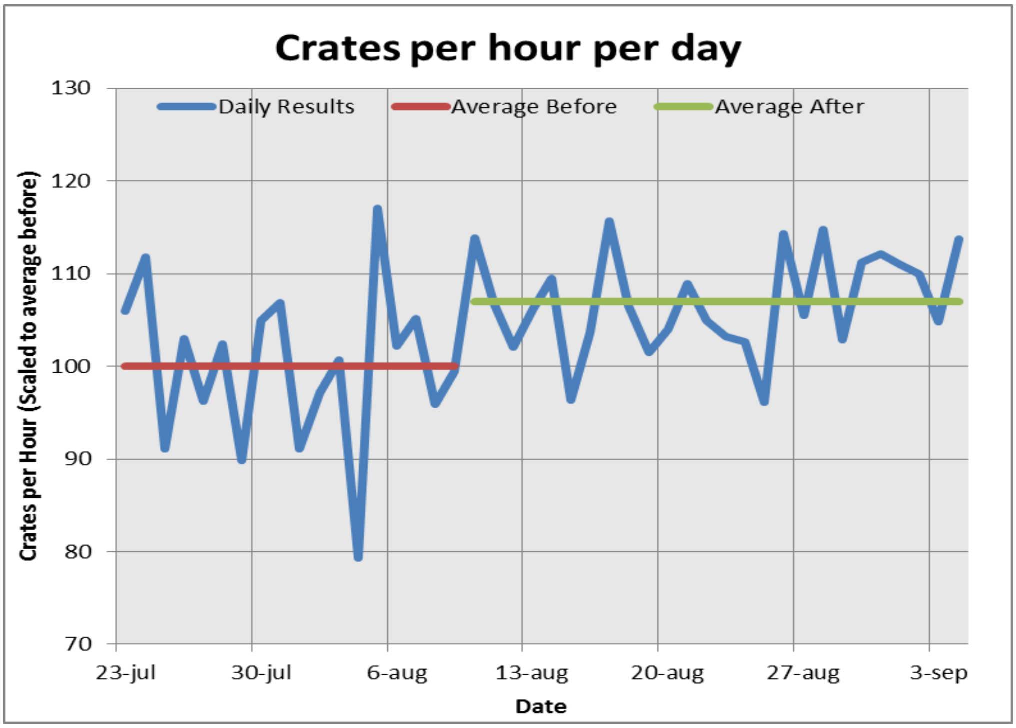

Figure 5-3 Performance KPI before and after changes

5.2 Working hours

The second problem for which we went onto the working floor was the problem with the capacity and thus the limit to growth. It was reported that some days the entire storage space for full containers was completely filled up while other days there was plenty of room available. After analysis of the different days and the patterns it quickly followed that after a day with a smaller buffer ready at the start of the day the next morning the storage space would be completely filled.

The problem here turned out to be the system in which the facility decides on working hours. After the storage space becomes empty almost all workers get sent home and the work for that day is finished. On a day where there is not a lot of work at the start of the day this means the time workers go home might be quite early. The main reason this is done is that the amount of work entering the facility when this buffer is empty is not enough to keep everyone working at a speed level as wanted in the KPI's. Another factor that does not help our problem is that no fixed schedules can be made since the demand varies too large between the same day in different weeks.

A solution to this problem would mean being able to handle more containers in the afternoon and thus having a smaller amount of containers waiting in the morning. A quick analysis of the data shows that during the hours of 06:00 to 08:00 almost no trucks reach the facility. Workers now work from about 06:00 until 15:00, which means they are present for about 54% of the trucks arriving. If work would start later at 08:00 until on average 17:00 the crew would be present for 62% of the trucks arriving. This would allow the workforce to be present longer in the afternoon with more work arriving at those hours and thus not leaving early.

<table>
<tr><th>TIME</th><th>Arrivals</th><th>Original</th><th>Shift 1h</th><th>Shift 2h</th></tr>
<tr><td>0 - 1</td><td>1%</td><td rowspan="6"></td><td rowspan="7"></td><td rowspan="8"></td></tr>
<tr><td>1 - 2</td><td>2%</td></tr>
<tr><td>2 - 3</td><td>2%</td></tr>
<tr><td>3 - 4</td><td>1%</td></tr>
<tr><td>4 - 5</td><td>0%</td></tr>
<tr><td>5 - 6</td><td>0%</td></tr>
<tr><td>6 - 7</td><td>0%</td><td rowspan="9">54%</td></tr>
<tr><td>7 - 8</td><td>0%</td><td rowspan="9">59%</td></tr>
<tr><td>8 - 9</td><td>3%</td><td rowspan="9">62%</td></tr>
<tr><td>9 - 10</td><td>5%</td></tr>
<tr><td>10 - 11</td><td>11%</td></tr>
<tr><td>11 - 12</td><td>14%</td></tr>
<tr><td>12 - 13</td><td>9%</td></tr>
<tr><td>13 - 14</td><td>7%</td></tr>
<tr><td>14 - 15</td><td>5%</td></tr>
<tr><td>15 - 16</td><td>4%</td><td rowspan="9"></td></tr>
<tr><td>16 - 17</td><td>4%</td><td rowspan="8"></td></tr>
<tr><td>17 - 18</td><td>5%</td><td rowspan="7"></td></tr>
<tr><td>18 - 19</td><td>7%</td></tr>
<tr><td>19 - 20</td><td>7%</td></tr>
<tr><td>20 - 21</td><td>5%</td></tr>
<tr><td>21 - 22</td><td>4%</td></tr>
<tr><td>22 - 23</td><td>2%</td></tr>
<tr><td>23 - 24</td><td>1%</td></tr>
</table>

Figure 5-4 Sum of workload covered during each shift

To test this idea a simulation is created to calculate the maximum size the queue reaches in the morning and whether making this change will reduce that queue. To show the results of the simulation we scale the size of the buffer on a normal day to 100 and look at the related results. As can be seen in the Table 5-1 the buffer would only reach 85 when shifting the hours back one hour, or even reach 82 when shifting the buffer back two hours. The hours worked remain the same and thus the KPI's don't change, while there is more room for more arrivals during the entire day.

However having less full containers in this case means having to store the empty containers. The schedule held by Hollander of shipping these to the main distribution center does not currently fit with the improvement as proposed. Since this is out of scope we aim not to change anything about other departments schedules, but we can propose that the departments look together if this is an option and test it accordingly.

Table 5-1 shows that the amount of empty containers rises by 8% when shifting a single hour and even goes up to a 36% increase when shifting two hours. While shifting the work two hours has a larger benefit than the single hour option its improvements are only slightly better. Combined with the rising amount of empty containers that need to be stored, shifting one hour would make a good option to test in the facility.

Name	Start	Avg End	MaxFull	MaxEmpty
Original	6:00 AM	15:00 PM	100	100
Shift 1h	7:00 AM	16:00 PM	85	108
Shift 2h	8:00 AM	17:00 PM	82	136

Table 5-1 The results and benefits of different starting hours

5.3 Splitting the sorting

For the next idea instead of looking at bottlenecks we decided to look at another aspect of the system in place. The bottleneck was identified as being the conveyor belt and it is the part where the utilization is the highest and more room can be created let flow more crates flow through. The other side however is looking at what resources have a very low utilization and might be combined in order to decrease the number of hours worked. Both would lead to the same increase in KPI's as they are simply calculated by the amount of work performed divided by the hours worked.

When looking at the working floor it can be quite clearly seen that the amount of work performed by workers sorting the CBL crates is a lot higher than the workers who sort the EPS crates. An easy explanation for this can be seen when looking at the data from chapter three. While 70% of the crates that enter the facility are CBL crates and 30% of them are EPS crates the EPS crates are foldable and can thus be stacked a lot higher. This means that only about 20% of the crate stacks on the conveyor are EPS type stacks.

Currently there is no way to prevent the mixing of CBL and EPS stacks on containers since this is performed by the supermarkets without regulation. Discussion with management however revealed that supermarkets could be convinced to put the different types on different containers in case that enough money could be saved. A new simulation opportunity thus arrives to assess whether this is possible.

Here however, some of the limitations of the model come in to play. Since we only know the speed at which people can sort the crates in the current situation it is difficult to extrapolate it to a new situation where the entire belt is filled with more of their type of crates. While we know that the current system can handle some randomness of large batches of one type we cannot assume that the speed that that requires them to work at can be performed a full working day. The solution to this question is thus split in two different parts, one of which is simulated and the other part is theorized. We will simulate the fact that part of the buffer now only hold EPS containers while the other part of the buffer only hold CBL crates and will theorize how many people would have to be working at the back side of the sorting to handle it.

The new situation would be as follows: There are separate storage locations for the two different types of crates. The 8 workers that now handle CBL crates and 5 workers that now work EPS crates are put into one general group of workers. If the belt is loaded with a certain type they all work on sorting that type. Depending on the amount of crates not all 13 people would be necessary for this thus creating a situation where less hours need to be worked.

The simulation showed that there would be no problem with separating the EPS and CBL crates before the actual sorting stage. As the EPS containers could hold more folded crates on a single container the 30% of crates only took on about 15% of the total space needed for full containers. An exact optimal point to switch between EPS and CBL sorting has not yet been determined but is also dependent on how long it would take to switch between two types; information that has to be found out empirically when testing. As long as almost all crates would be delivered sorted to the facility the improvement effort was deemed feasible.

The next step was finding out how many people would be needed to perform the sorting of the crates of a single type. For this the data on stack percentages is important. For the calculations we only use the CBL side as we know that their time spent actually working is the highest. About 50% of the stacks that would be sorted with a mixed batch would be CBL Type E and Type F. To sort these crates 4 of the total 8 CBL workers would be tasked with either one of these two types. This would implicate that a single worker can handle about 12,5% of the total stream on the conveyor belt. If either CBL or EPS thus only had their own type come past an workforce of about 8 (100% divided by 12,5%) could be enough.

A second option to get an idea of the amount of people that would be needed is to assume the total workload a certain team has. The 8 CBL sorters would in the normal situation handle about 80% of the total amount of crates, each performing 10%. Thus if there were 100% CBL crates a team of 10 (100% divided by 10%) would be needed to perform all the work.

Since both options are close to each other but have a different way of approach, the rest of these calculations will take their average of 9 people in the back of the belt workforce compared to the original 13. Since our simulation shows the idea as feasible this would save on four workers every single shift. The full sorting workforce as measure in the Sorting Performance KPI comes down to about 26 workers on average. Reducing the sorting force to 22 workers would save about 15% of hours made. If we assume a working schedule of 40 hours a week, 52 weeks a year this would create yearly savings of 8320 hours times the pay rate. For this reason we advise Hollander to start a trial by asking some supermarkets to start delivering their crates sorted so that more specific data can be measured.

5.4 New counting machines

Another idea that was presented by management was the plan of a new way to count the crates that pass through the system. Currently the crates are counted after they're taken off of the retraceable container so it is not possible to determine where the crates came from. When the sorting facility aims for more growth and potentially more partners it would be necessary to determine which empty load bearers came from what store or partner. A second benefit to this would be that the cell spaced conveyor could be taken out of commission to create a better flow.

There had already been talk on the idea of this sorting machine but the feasibility was not known yet. For this reason the idea was picked for this project in order to use the simulation to calculate the possibilities. The counting machines would be machines that can count an entire containers full of crates at once. It would require extra resources in order to get these containers counted but management decided that that cost would be lower than the benefit counting them precisely gives. In order for this idea to be feasible a certain amount of these counting machines would have to be placed into the step after unloading the truck and before the full containers are stored into the buffer. This means that before the idea can be feasible we need to determine what amount of machines would provide enough throughput.

For this manner a new model in Simio was created. If we just want to know how much the machines can handle a simple two server model in series would be enough. The requirement for this model is that the buffer for the full containers does not empty before it would in a normal situation. We can assume both the input and the output as black boxes so we get a model that is able to run quickly while still using all the data from the normal model.

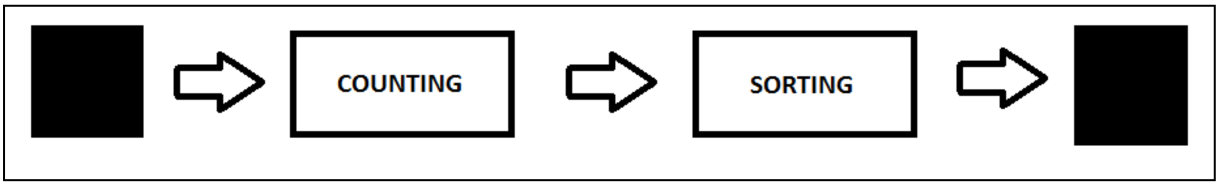

Figure 5-4 Schematic of the additional counting model

The counting section here has a variable amount of servers depending on how the variables are set. Since room is limited the project is mainly feasible if three counting machines can process fast enough without the sorting section running out of work or the buffer becoming too large. The schedule of these servers is set to full at times when arrivals take place with some extra scheduled servers as backup for straggling trucks that arrive in the middle of the night. The time it would take to count a single container is estimated at 60 seconds but we will run the simulation for more optimal durations as well. For the sorting section and the input black box all parameters from the original model are taken.

Fifteen different simulations were run with each one differing between 1 to 5 machines with a working time between 60, 50 or 40 seconds. The balanced score again is 100 on a rational scale with the possible solution aiming for that score of 100 and not going over. The final outcomes after several rounds of each simulation can be found in the table below.

From the results we can read that a score of about 100 without going over 3 machines only exists in the case that the counting takes between 40 and 50 seconds. As this is not what the current expectations are for the machines the advice to Hollander is to not invest in such a solution until either technology improves or there is more room available to place these machines.

Counters / Time (s)	1	2	3	4	5
60	295	185	120	101	101
50	211	134	104	100	100
40	156	115	100	100	100

Table 5-2 Results for the number of machines and processing times

6. Conclusions

In this project a research question was asked that could be divided in two main parts. Improvement efforts that could help Hollander as well as a model that could be used to test them. While the research question was formulated as a single sentence we will conclude them separately. They together from the answer to the question "*How can the effectiveness of improvements to the returns department be examined and what can be done to increase the capacity and cost-effectiveness of the return department*"**.**

6.1 Conclusions on the Model

The sub question that ultimately led to the creation of the model was "How can we test proposals for improvement without disturbing day-to-day work." The answer to this question is that multiple types of models might be possible but that the object oriented visual simulation model created in Simio can already answer the question by itself. As can be seen in the chapter on improvement efforts the model can be a great help by allowing the user to see the difference between the current situation and a fictional situation that is proposed.

While the improvement effort on conveyor speeds had a lower effect than the simulation expected this was already predicted before the simulation was run. The fact however that the results of the simulation turned out to be effective in the real life scenario is another piece of knowledge to the fact that the simulation is a functional way of testing improvement efforts. It can thus be concluded that with the newly created model improvements can be tested without disturbing the day-to-day work.

6.2 Conclusions on the Improvement Efforts

We took a focus on improvement efforts to answer the questions "What methods can Hollander use to improve the cost-effectiveness of the returns department" and "What actions can Hollander take to allow for growth in the returns department". To answer these questions several simulation runs have been performed and the results are clear.

To improve the cost-effectiveness there are already two clear options that show from the results. The first option of increasing the speed of conveyor belts is already implemented and shows an increase in crate throughput of almost 10% over the past few months. The bottleneck on this spot in the cycle has been severely loosened and cost-effectiveness has thus increased.

The second option that was proposed on the subject of cost-effectiveness was to start asking the supermarkets to pre-sort the crates between the two different CBL and EPS types. If both of these types can be run through the system one by one the effort in the back of the sorting system can be greatly reduced. The model is showing that when implemented this could save about 30% of the hours on the back of the conveyor belt which equates to roughly 15% of the hours the entire sorting system creates. Savings could go up to 8320 hours per calendar year without reducing the KPI showing that this option can also greatly increase cost-effectiveness. Hollander is thus strongly advised to go in to talks with supermarkets to set up a trial period.

With the question on allowing growth less success was achieved. The first proposal of changing the scheduled time of workers to either one or two hours later could be a success and reach a 15% decrease in buffer space but this solution depends on possibilities within the transport department. If transport could switch their schedule to match better with the return facility or could create a buffer of empty containers themselves this solution might still be useable in the future.

The second option was even less successful than the first but the impact of that result was still positive. For the counting machine simulations the aim was still on allowing for more growth but the idea came from management planning. The fact that the results from our simulation show that the counting machines are not feasible in the current set-up is a unfortunate but it still prevents the company from making expenses they should not have by shutting the project down early. Our simulation thus didn't find a conclusive answer to the sub-question but it did prevent other non-solutions from changing the work method.

6.3 Implications and Future Research

Results from the simulation show that the use of a simulation model is very effective to test new efforts while not disturbing the day-to-day work too much. For Hollander this means that the model can be used in the future in order to test any new ideas that may present itself.

For future research it may be interesting to see what the model can do if we allow some disturbances to the day-to-day work to happen. An example found in this report is the lack of knowledge of handling speeds when the pressure is higher. This could simply not be tested without taking a lot of time testing it on the working floor thus incurring more costs than this modeling effort. An interesting question to answer could be how much better the new model would be able to predict answers to our third improvement effort of splitting the crate sorting.

7. References

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Software used

Simio, Licensed by Hollander, https://www.simio.com

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