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Specialization: Production Engineering and Logistics

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Title: Increasing the efficiency in space usage for the Damen Shipyards central warehouse in Gorinchem

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Initiator (university): Prof. dr. ir. G. Lodewijks

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Subject: **Increasing the efficiency in space usage for the Damen Shipyards central warehouse in Gorinchem**

The Damen Shipyards Group has grown rapidly in the past decade. The growth pushed the supply chain organization, and especially the Central Warehouse, to the maximum of its current abilities.

Background

The Central Warehouse (CW) in Gorinchem (the Netherlands) forms a central hub in Damen's global supply chain: here, the majority of the materials are checked, registered and consolidated before being shipped to the specific yards. The processes are challenging, as it is characterized by (very) short lead times, a large variety in materials, and a variety of destinations and the accompanying requirements.

In the near past, Damen's CW was struggling to keep up with the growing material flows. As a result, late and incomplete shipments were pushing the organization's flexibility to the limits. To relieve the organization, the CW in 2013 temporarily moved to a larger location.

The general management has however stated that in two years (2015), the warehouse will move back to their previous facility. In order to prevent the problems from reoccurring in the future, the organization and flows through Damen's warehouse urgently need to be revised.

Problem definition

In light of the described situation, the management of Damen's Central Warehouse would like a design and advice for their 2015 Central Warehouse. This includes the material flows and the accompanying processes, both from a physical as well as an organizational perspective. The improvements should lead to more space efficiency in order to return to the previous warehousing facility.

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Research question

What can Damen change in the order flow to reduce the amount of goods in the central warehouse and how can these goods be handled more efficiently within the central warehouse so that a return to the previous warehousing facility is made possible by July 2015?

Execution

1. Analyze the processes that directly influence the space usage in the central warehouse by using the Delft Systems Approach
2. Categorize and quantify the space usage
3. Improve the processes per category to reduce space usage
4. Create conceptual process designs that can be used to return to the previous warehousing facility
5. Specify requirements for conceptual process designs
6. Study relevant literature

The TU professor,

Prof. dr. ir. G. Lodewijks

The TU supervisor,

Dr. ir. H.P.M. Veeke

Increasing the efficiency in space usage for the Damen Shipyards central warehouse in Gorinchem

by

T. N. van Milligen

in partial fulfillment of the requirements for the degree of

Master of Science
in Mechanical Engineering

at the Delft University of Technology,
to be defended publicly on Friday June 13, 2014 at 14:00.

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	Prof. dr. ir. G. Lodewijks,	TU Delft

This thesis is confidential and cannot be made public until June 13, 2016.

Preface

I would like to express my gratitude towards Damen Shipyards for their warm welcome. Everyone was always available for a chat or to discuss problems and possibilities for the company. I would like to especially thank my direct supervisor Arie Peursem for always having his door open for me. The ability to discuss every idea I had certainly helped the quality of this work. The guys from the incoming goods section deserve a personal thanks because they dragged me out to take a break sometimes. I loved that I had the opportunity to present my findings multiple times in front of an audience including the supply chain director and several other important people within Damen.
I would like to thank Hans Veeke, my supervisor in Delft, for getting me in contact with Arie Peursem, and for always guarding the quality of my work. Gabriel Lodewijks and him both had the ability to make me rethink everything I did, so that the end result would become so much better.
The support Marthe Korte gave me by making me look at the big picture all the time and reading everything countless times was incredibly valuable to me. The last thanks go to Martin Bakker, who always took the time to listen to my stories and read my report.

T. N. van Milligen
Delft, 28 May 2014

Summary

Can Damen return to the old warehousing facility? The short answer is yes, but no. When viewing the central warehouse as a distribution center, the required space can be reduced to much less than is available in the old warehouse. However, because the warehouse is often used as a storage facility, a return is made impossible.

At this time, 4200 m^2 is used for receiving the goods, 8200 m^2 is used for temporary storage, and 6400 m^2 is used to create the shipments. By changing the categorization of the incoming goods and going to a one-buffer system, the section for receiving goods can be reduced to less than 1000 m^2. The temporary storage now uses 8200 m^2, but this is caused by the average time in storage of almost 9 working days (Little's law). This means that goods are 9 working days too early (on average). By changing the mindset that 'then at least we'll have it' internally and by giving clear feedback internally and to the supplier, this can be brought back to less than 1200 m^2. By changes inside the central warehouse (disregarding the changes outside of the span of control of the central warehouse), the current amount of goods can be stored more efficiently in 3000 m^2. By generating a continuous flow for the outgoing goods and by eliminating the enormous time loss created by slow scanners, the outbound process can be done with less than 2000 m^2. This would easily allow a return to the old central warehouse, offering 6700 m^2.

All this being said, Damen keeps on storing more and more goods for extended periods of time and both warehousing facilities become fuller and fuller. This is caused by leftovers from finished projects (ranging from custom made propellers to more standardized parts). Some of these leftovers have been there for more than five years and might still be there for five more because they have once cost a lot of money. Besides this, canceled or delayed projects form a large part of the storage area and according to Damen 'this will never change'. On top of all of this, Damen has expressed that 90% of the flow of goods only accounts for 10% of the value and that this should just 'be there' so that it won't delay the other 10% of more costly items. Although this is understandable, this can be translated to a lack of willingness to change the attitude 'at least then we'll have it'.

When regarded as a distribution center, there will be no problem in returning to the previous location with some changes in the process. When including the enormous amount of stored goods that is continuing to grow, there is no possibility of returning and in a few years, even the total of 24000 m^2 will not be enough.

Summary (in Dutch)

Kan Damen terugkeren naar het oude magazijn? Het korte antwoord is ja, maar nee. Als het centrale magazijn wordt gezien als een distributiecentrum kan de benodigde ruimte teruggebracht worden naar veel minder dan wat er beschikbaar is in het oude magazijn. Doordat het magazijn echter veel gebruikt wordt als opslagfaciliteit wordt een terugkeer onmogelijk gemaakt.

Op dit moment wordt 4200 m^2 gebruikt voor de goederenontvangst, 8200 m^2 voor tijdelijke opslag en 6400 m^2 voor het creëren van verschepingen. Door minder te categoriseren bij de goederenontvangst en door over te stappen naar een systeem met maar één buffer, kan de goederenontvangst worden afgehandeld in minder dan 1000 m^2. De tijdelijke opslag gebuikt nu 8200 m^2 , maar dit is veroorzaakt door een gemiddelde ligtijd van bijna negen werkdagen (de wet van Little). Dit betekent dat goederen gemiddeld negen dagen voordat ze nodig zijn arriveren. Door de mindset van mensen te veranderen waarbij een vroege levering wordt gezien als 'dan hebben we het maar alvast' en door goede feedback te geven (intern en aan de leverancier) zou dit teruggebracht kunnen worden naar minder dan 1200 m^2. Als hier niets in verandert dan zou de huidige goederenstroom efficiënter kunnen worden opgeslagen in 3000 m^2. Door een betere doorstroming te krijgen bij het creëren van de verschepingen en door het tijdverlies van de langzame handscanners te elimineren kan dit proces afgehandeld worden in slechts 2000 m^2. Hiermee zou een terugkeer naar het oude magazijn van 6700 m^2 mogelijk zijn.

Dit alles gezegd hebbende blijft Damen meer en meer goederen opslaan voor langere periodes en beide magazijnen worden steeds voller. Dit wordt veroorzaakt door overblijfsels van projecten (dit zijn bijvoorbeeld scheepsschroeven die op maat gemaakt zijn voor een specifiek schip, maar ook veel gestandaardiseerde onderdelen). Sommige van deze overblijfselen zijn al meer dan vijf jaar opgeslagen en zouden zo nog eens vijf jaar opgeslagen kunnen blijven omdat ze ooit veel geld gekost hebben. Hiernaast zorgen geannuleerde en vertraagde projecten ook voor een grote vulling van de opslag en volgens Damen gaat dit nooit veranderen. Verder heeft Damen geuit dat negentig procent van de goederenstroom bestaat uit goederen met tien procent van de waarde en deze goederen 'moeten er gewoon zijn' om de overige tien procent duurdere goederen niet te vertragen. Hoewel dit goed te begrijpen is kan dit vertaald worden naar een gebrek aan wil om het 'dan hebben we het maar alvast' te veranderen en dit zal een terugkeer onmogelijk maken.

Als het magazijn wordt gezien als distributiecentrum dan is het mogelijk om terug te keren naar het oude magazijn met een aantal veranderingen in de manier van werken en de manier van opslaan. Wanneer de enorme hoeveelheden opgeslagen goederen in acht worden genomen en wanneer opgemerkt wordt dat dit steeds meer wordt dan is er geen mogelijkheid om de gewenste functie te verrichten in zoveel minder ruimte en dan zal zelfs de totale 24000 m^2 op den duur niet voldoende zijn.

Contents

List of Figures

List of Tables

1 Introduction

Damen Shipyards has expanded its central warehouse because they claim they were not able to handle the flow of goods without making errors with their method of work. The errors consisted mostly of lost materials and incomplete shipments. The expansion was intended to be a temporary measure in order to improve the process in such a way that a return to the old location would be possible. To clarify the role and function of the central warehouse within the Damen Shipyards Group, and to get insight into the research, the following sections are written.

1.1. Damen Shipyards Group[1]

So what does Damen Shipyards do? The Damen Shipyards Group is a Dutch family owned shipbuilding company with sixteen shipyards in the Netherlands and twenty-two abroad. Its head office is in Gorinchem, where it also has a shipyard and the central warehouse through which the majority of parts for all boats are distributed. Damen builds a wide product range around the world including tugs, workboats, fast ferries, cargo vessels, patrol craft, dredgers, and mega yachts. They have built more than 5000 vessels since 1969 and add more than 150 vessels a year to that. This together with the completion of around 1000 repair jobs per year generates a yearly turnover of 1.7 billion euro.

1.2. Central Warehouse Gorinchem[1]

The central warehouse has a number of functions, of which the most important are receiving, consolidating and sending goods that are meant for boats built at one of the 38 Damen Shipyards in fifteen countries all over the world. Another function is the receipt and shipping of spare parts and parts for repair jobs. The central warehouse also stores goods that are used more frequently. For these inventory items, the central warehouse functions as a storage facility.

To be able to return to the old warehousing facility, the functions that are now executed in both the old warehousing facility (offering 6700 m^2) and the new warehousing facility (offering 18800 m^2) have to be done in the space offered by the old warehousing facility. There is, if absolutely necessary, an option to add approximately 3500 m^2 to the old warehousing facility.

The central warehouse was situated next to the head office in Gorinchem until July 2013. It moved to a rented facility nearby of which the first two years were relatively inexpensive. The scale difference between the old warehousing facility (West) and the new warehousing facility (Oost) is visualized in figure 1.1. For additional scale reference, a standard truck with a 13.6 meter long trailer, fork lift trucks and Euro-pallets (0.8 m $\times$ 1.2 m) have been drawn. The general layout of the new warehousing facility has been drawn. Some quick elaboration on this: On the right, the goods arrive and are checked, in the middle they are stored and on the left they are consolidated and prepared for shipment.

[1]The information about Damen Shipyards is taken from the key figures and other public information on www.damen.com

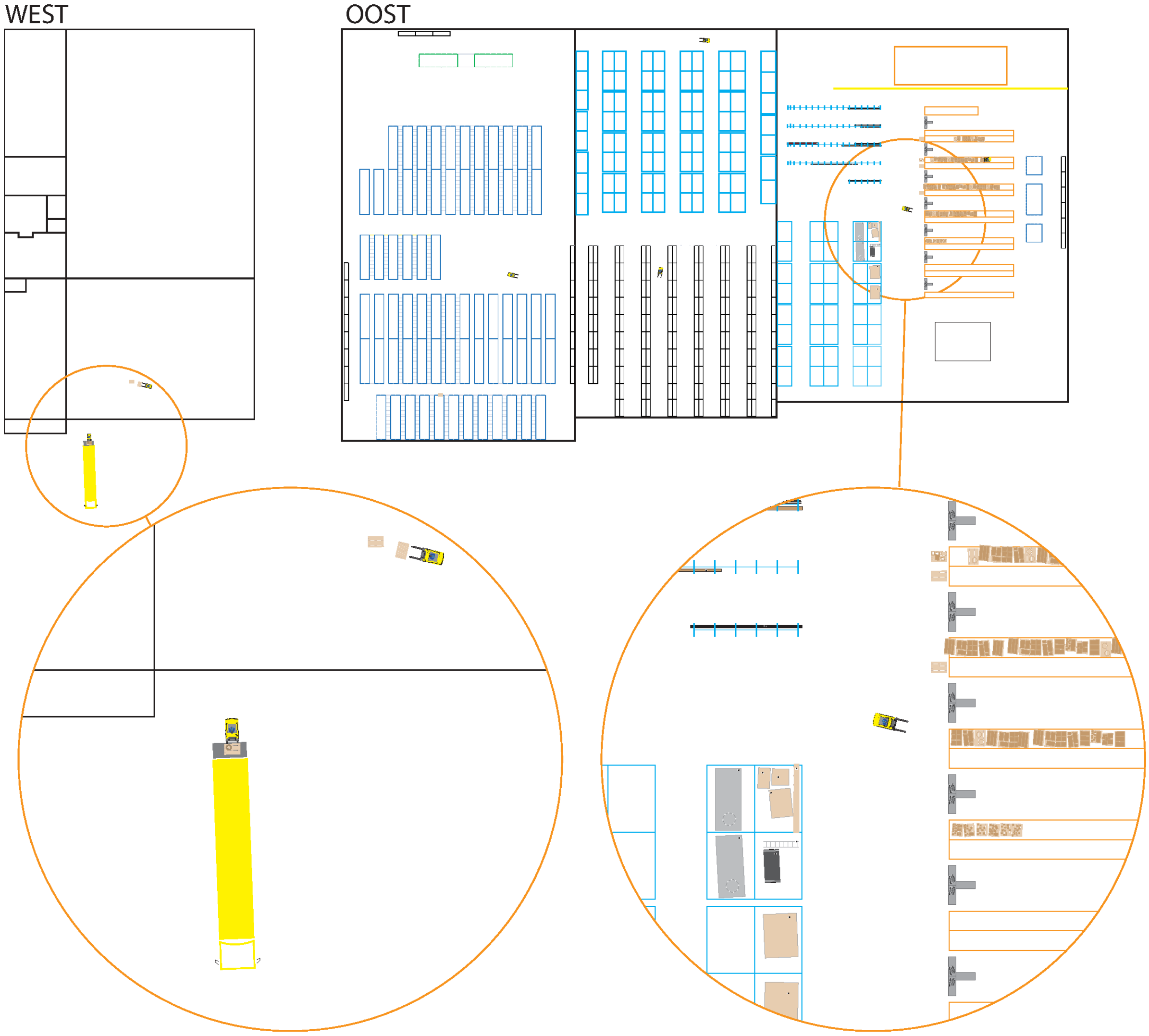


Figure 1.1: Difference in the schematic layout of the warehouse facilities. 'Oost' is the current warehouse

1.3. Material flow through central warehouse

Figure 1.2: Example of variety of goods that come through the central warehouse in Gorinchem

The material flow consist of parts varying from emergency generators and screw propellers to bolts, paint and toilet bowls (an example of this variety is shown in figure 1.2). Almost everything to finish a boat that does not exceed the maximum of 10 cubic meters or 4000 kilograms goes through the central warehouse in Gorinchem. Every order is either bought for a boat made at one of the Damen Shipyards or is meant to refill the inventory. An order can consist of several items from one supplier called 'lines' as is illustrated in figure 1.3. More than a thousand suppliers send these items to Damen Shipyards Gorinchem resulting in an average of 1020 lines arriving per day divided into 204 orders. These are then checked for quantity and labeled with Damen labels and subsequently put into storage. In due time these items will be combined into packaging units fit for the method of shipping and then those packaging units are mostly put into standard twenty- or forty-foot containers. According to the planning department this process should take around three weeks.

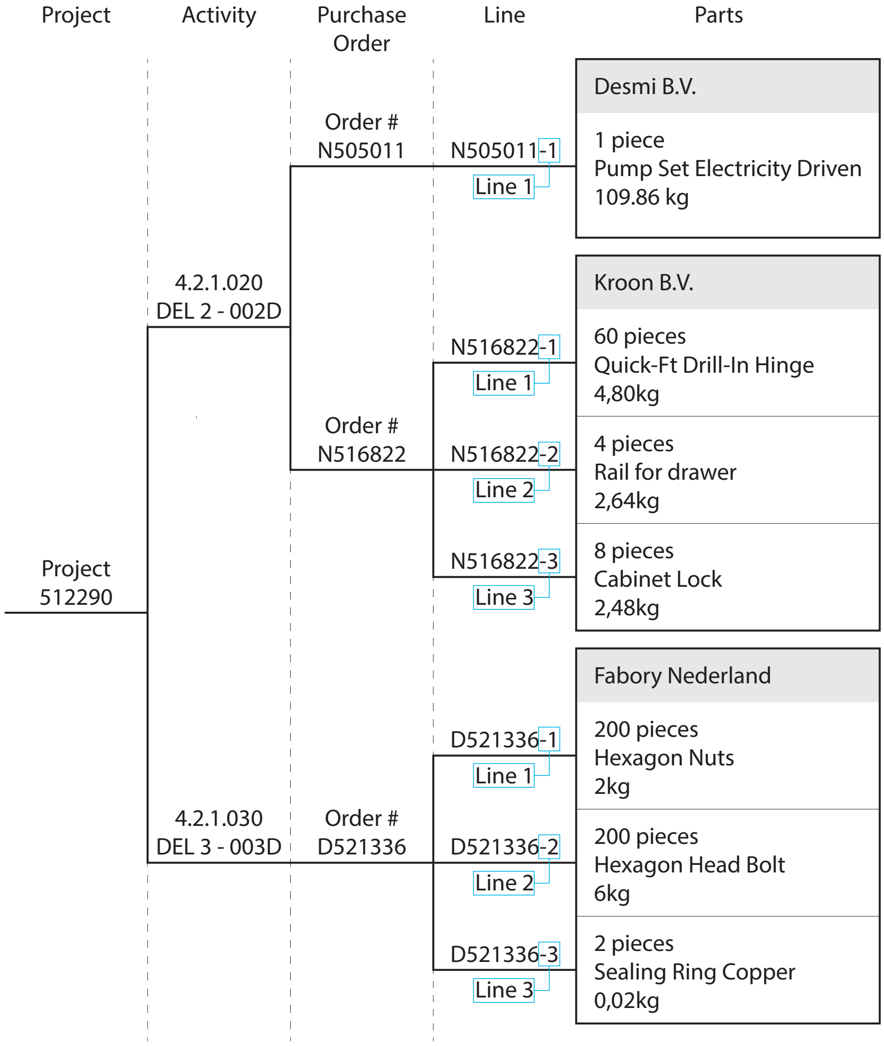


Figure 1.3: Explanation of order structure

Figure 1.3 illustrates the order structure. It starts with the highest level of the order, namely the project number. This identifies the boat that is being built. The project contains activities that are indicated with numbers (4.2.1.020 indicates instance 20 of an incoming logistics activity), these activity numbers are also shown in a Damen figure (2.3) on page 8. There are activity numbers for all phases of the project and they are named to indicate what it is for. In the example two activities can be seen, one for the second delivery and one for the third delivery. The goods are ordered and every order from one supplier for one activity gets an order number like displayed in the third column. The different parts in this order are then indicated with line numbers as shown in the fourth column. In one of those order lines, there could be multiple pieces of that part and it can have a variety of weights as shown in the last column. One order number is always from one supplier, as is illustrated by supplier names in the last column.

1.4. Warehouse performance

The performance of the central warehouse is largely dependent on its ability to ship goods in time. The milestones to define 'in time' are called activities and have been planned at the start of the project, also shown in figure 1.3. These activities are formed by taking the moment the goods should arrive at the customer and then counting back. The times between the different activities in a project are shown in figure 1.4 and can be defined as:

- Transport
  The shipping time depends on the distance to the customer and the mode of transport to come to the moment the goods should depart from Gorinchem. That moment is the end date of the outbound activity called 4.2.2 (extra clarity into these numbers will be given later on).
- Consolidate
  The time to consolidate the goods at the central warehouse. This normally takes two weeks for outgoing goods. If this time is subtracted, the start date of the outbound activity is set. It then takes a maximum of two days for incoming goods to process them, but five workdays are given. If that time is subtracted, the inbound activity is set
- Supplier lead time
  Supplier's lead time and purchase time. In total this takes eight weeks, but goods with shorter lead times will be ordered closer to the inbound activity so the eight weeks available are a combination of purchase time and supplier lead time. Goods with lead times longer than eight weeks get an activity starting with 3 and will be ordered earlier. To indicate when these long lead time items should arrive in Gorinchem, they are connected to an inbound activity (called 4.2.1), others will directly be connected to the 4.2.1 activity
- Translate to materials
  Drawings are translated to purchase requisition orders by Material Coordination. This normally takes two weeks and before that, the drawings for those shipments should be finished by the Engineering Department

These activities are used to give all departments clarity into what their task is and what their deadline is.

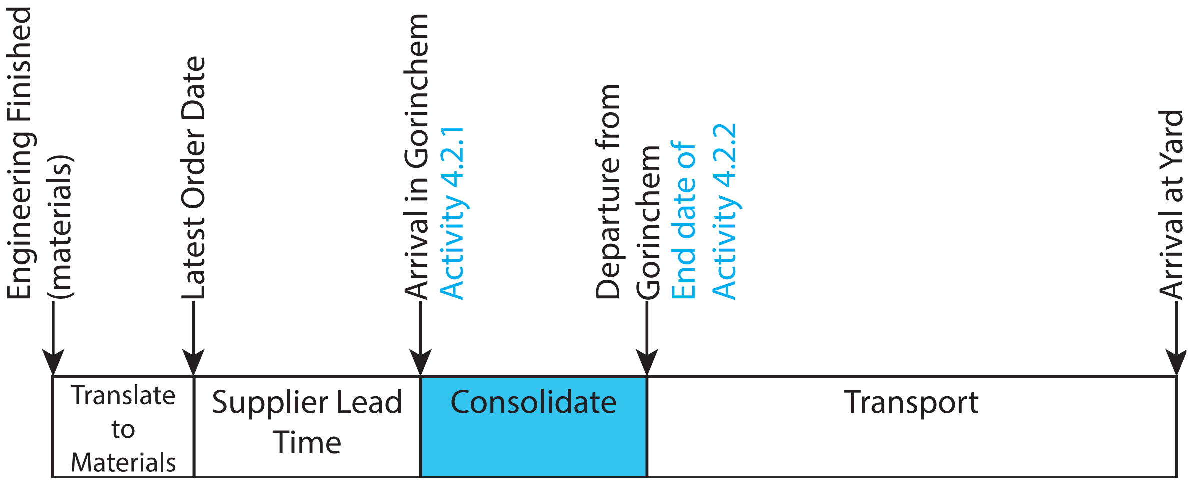


Figure 1.4: Schematic representation of the supply chain. The central warehouse is indicated with blue coloring
Source: Author

The central warehouse receives goods from many different suppliers and sends it (consolidated) to many different shipyards. If all parts arrive on the date marked 'arrival in Gorinchem' in figure 1.4, the central warehouse has more than enough time to ship everything before the end date of the outbound activity since the planning includes certain buffers. Most progress is registered in the Enterprise Resource Planning (ERP[2]) software via hand-held terminals (for an example of such a terminal, see figure 2.1 on page 6). The data that is created in the process will be used to analyze the flows through the central warehouse.

[2]The ERP software used at Damen Shipyards Gorinchem is IFS (Industrial and Financial Systems) Applications. This software went live on June 1st 2011 and is used throughout the company. The hand-held terminals run Windows Mobile Server and use software provided by Radley Corporation, which is a partner of IFS

2
Process Description

In this chapter, the process will first be explained to get a feeling for the research. The ultimate goal is to find a way to increase the efficiency in space usage in such a way that a return to the previous warehousing facility is made possible. In section 2.1 the entire process will be explained after which certain aspects are elaborated in the sections that follow. A rich picture, showing the process with the issues per step is shown in figure 2.2.

2.1. Description of the existing situation

Before any work can be done on an order for a ship, Design and Proposal (D&P) makes the specifications for the ship with the sales department, of which the latter handles the communication with the customer. D&P then cuts the order down into smaller portions that need to be done in order to finish the project. D&P also assigns the available hours and budget to the portions they have just created.

The Project Managers (PM) then translate these hours and budgets to activities to which they can assign available hours and deadlines using the template from a similar project or from the so called 'mother of all templates', which provides a complete basis that can be altered to better fit the project. During a kickoff-meeting with the entire building team these assigned hours are discussed and redistributed after which the departments can start working on the project and declare their hours for that activity.

The pieces of the order are then processed (according to the planned start and end date). This is firstly done by the engineering department, which engineers the sections in the number of hours given in the activity. When a batch of drawings is done, they are sent to material coordination. This department translates the drawings into required parts and makes sure the needed parts are ordered. This can be done by making a purchase requisition order that can be handled by the purchase department, or, in certain cases, by their own department. The need for materials can also be filled in by reserving them from inventory. Before goods are actually reserved from inventory, a need is entered in the ERP-system. It is up to Part Catalog (PC) to keep the inventory level high enough to meet the needs that are entered in the system. A short time before the outbound activity starts, these inventory items will be reserved from inventory and transported to the outbound-side of the central warehouse.

The normal way for an order to be processed begins with the purchase requisition order that is made in IFS applications and contains a latest order date and a wanted receipt date. The requisition is then handled by translating it into purchase orders of which a portion will go directly to the customer's[1] yard (direct deliveries) and a number of parts will go through the central warehouse in Gorinchem. These purchase orders contain a wanted delivery date (communicated to the supplier), a promised delivery date (a response from the supplier) and a planned delivery date (an expected arrival date). Parts that are actually destined to go through the central warehouse in Gorinchem can still be sent directly to the customer if the goods are too large or too heavy to handle, this is done by the transport coordinators. When the goods arrive at the central warehouse, the packing list is compared to the purchase order in the ERP-system. As a result, the lines (into which all orders are divided) with their quantity on the

[1]The customer can be an independent shipyard or a Damen shipyard anywhere around the world

packing list are given the status 'to be received' in the purchase order. An arrival sheet with the location to unload the goods is then given to the fork lift truck driver. For legal reasons, no unauthorized personnel may enter the warehouse, so this unloading cannot be done by the delivery company. If it is unclear what project a delivered package is for, it will be put into a separate storage, in which items are placed that can not be processed for whatever reasons.

The arrived goods are placed into dedicated checking lanes according to what is said on the arrival sheet. There is one checking lane for large and long goods, there are four for normal goods, one for goods destined for Gorinchem, two for the services department and two for rush orders. The arrival sheet is then attached to the palletized goods in the checking lanes so they can be identified by the personnel checking the goods.

All goods are processed according to the FIFO (first in - first out) model. The goods are all checked for quantity and are labeled with Damen labels (with unique part barcode) so that they can be recognized (in the warehouse and at the customer's shipyard). Goods that are delivered in crates by trusted suppliers are not opened, the labels for the contents are printed and the stack of labels is put outside the crate. In this process, the goods are labeled as 'approved' in the purchase order. All goods that are processed are given a movable unit number with barcode for easy identification. This allows everything in that movable unit to be moved at the same time with one barcode.

All goods are palletized so if an order with a single item comes in they are either put on individual pallets or put on pallets for the same project number. The goods are then put into storage according to their destination and project number. The location of the goods is then stored in IFS in order to be easily found.

When the planning dictates that an outbound activity should start and there is no indication that this project is on hold (this would be indicated with a field where the words 'on hold' are written in IFS and must thus be checked), shipments are created by Central Warehouse Support (CW-Support) with all goods that are present and belong to that activity (or to an activity within that project that should have been sent already but hadn't arrived yet). They subsequently create a picklist with all these items by which they are blocked from being moved in the warehouse. The available quantity in IFS then changes to zero.
The shipment-number is printed with a barcode that can be recognized by the handheld terminals (figure 2.1). When the barcode is scanned, the picklists in the shipment are shown and when selected, the contents of the picklist are shown. Goods are then taken from the storage to a staging area. In the handheld terminals, the new location is then given for the movable unit (and thus everything inside it), but nothing in IFS indicates that anything has changed. The location for the items, shown in IFS, is still in the storage area until the goods are shipped, which makes them digitally 'lost' then.

Figure 2.1: Handheld-terminals with Radley software
Source: www.Radley.com

When enough goods are present in the staging area (according to the employee), the picking process will begin. At Damen Shipyards Gorinchem, this means that the items are individually put into handling units that are printed there by using the handheld terminal (the handling unit also has a barcode). A handling unit can be used to define a number of things, ranging from bundles of pipes to folding crates or sealed pallets. The handling unit labels have a different color so that it is clear that they are picked. When it appears that either a container can be filled or the shipment is complete, the handling unit numbers with their weights and sizes will be handed over to CW-Support (on paper). They will give these to the responsible material coordinator (which has five workdays to make the packing lists for the shipment) and to the transport coordinators (which will arrange the transport in the same five workdays). When the container leaves the Damen terrain, it is set to 'Delivered' in IFS. After the papers are handed over (while MC prepares the packing lists), the container is prepared by a specialized company (Schijndel Industriële Verpakkingen). They build custom structures in the containers to ensure safe travel. The administration for what actually goes into the container is done with paper lists with the handling unit numbers written on them, which they will manually check.

2.2. Situation displayed in “rich picture”

The flow described in the previous section is drawn in a rich picture in figure 2.2, also showing the issues that the various departments are having.

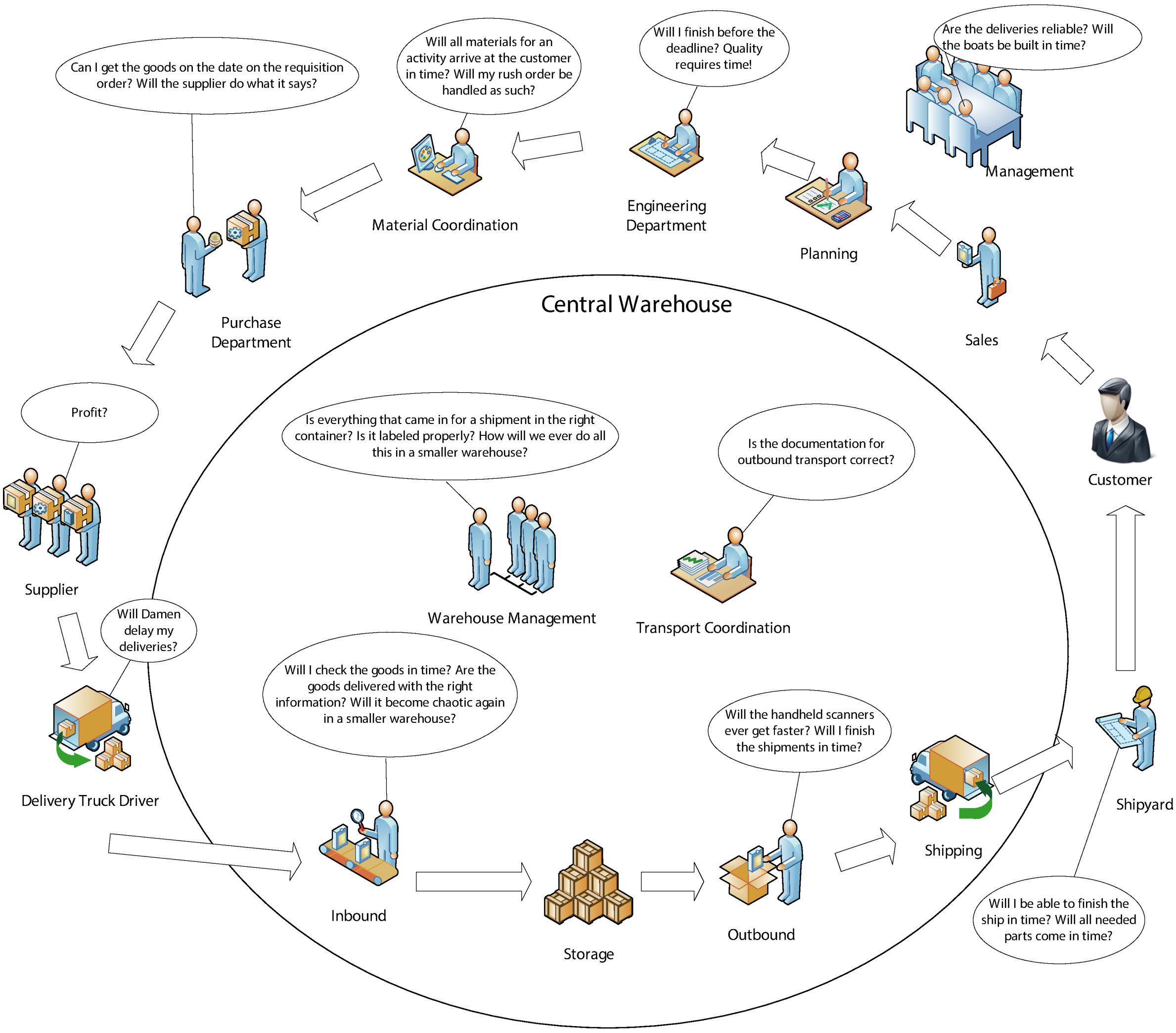


Figure 2.2: Rich Picture

2.3. Planning in practice

Items should be shipped in time from the central warehouse in Gorinchem for the whole process to be considered as well-functioning. The day the goods should depart from Gorinchem and other important milestones are set at the beginning of the project by the planning department. The logistic schedule that is used by the planning department is shown in figure 2.3.

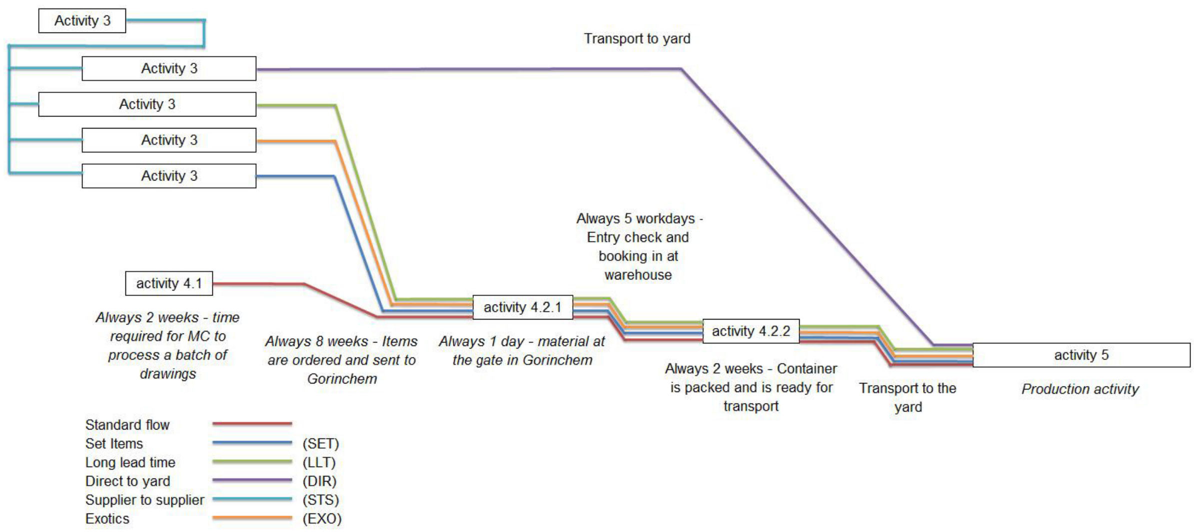


Figure 2.3: Damen planning for flow of goods
Source: Damen

The most relevant dates in the warehouse are linked to activity 4.2.1, which indicates when the goods should arrive, and activity 4.2.2, which indicates when the outbound activity should start, and when it should finish, these are also shown in figure 2.4, in which a simplified interpretation of figure 2.3 is shown. The original figure shows that one day is planned for the arrival of the goods, which means no more than that the goods are unloaded on that day. The activities 3 in figure 2.3 are for goods with a longer lead time. They are connected to an activity 4.2.1 for the inbound date. After that, five workdays are planned to check the goods and put them into storage. To consolidate all the goods in order to finish the shipment, two weeks are planned after which the transport to the customer is arranged.

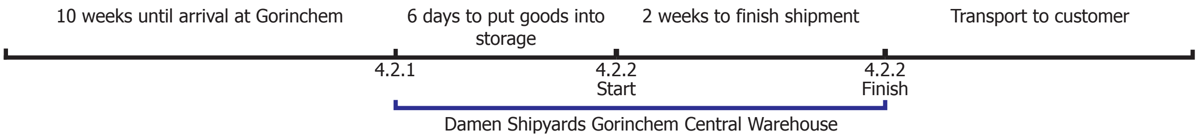


Figure 2.4: Damen planning for flow of goods (interpretation of figure 2.3)

Whether or not the central warehouse functions well is measured by the ability to finish the shipments before the end date of activity 4.2.2 in figure 2.4. The performance does not meet the requirements because parts do not come in when planned and not all items are shipped when planned. If goods come in too late, they are either rushed to process for the right shipment, they are sent with a next shipment to that yard, air transport or even a courier service is used. The actual throughput time is directly relevant to the amount of needed space by looking at Little's Law (Little, 1961) seen in equation 2.1 which dictates that the expected amount of items in a system is the expected time spent in the system multiplied by the arrival rate.

$$L = \lambda W \tag{2.1}$$

Where:

L: expected number of items in the system
$1/\lambda$: expected time between two consecutive arrivals to the system
W: expected time spent by an item in the system

The warehousing function needs too much space, which could indicate that L in equation 2.1 is too high, which is caused by too much input for the system (λ), or that the expected time spent in the system (W) is too much (which could be caused by the planning department and should be investigated). Another explanation would be inefficient use of space, which would increase the average space usage per item.

This is part of the responsibility of the warehouse manager and is commonly regarded as the easier approach in companies because it involves the least amount of change in the supply chain. The chain from planning department up to the purchase department is responsible for a 'planned delivery date' that closely corresponds with the actual needed date to ship the goods in time. The graphs in figure 2.5 and figure 2.6 indicate that this process is not functioning properly and this should be investigated further.

For the graphs in figure 2.5 and 2.6, only the activity dates that are used for the inbound process are taken. This excludes 20478 of the 89002 lines in the data set, which are mainly spare parts and/or parts for the service department. These are planned in a different way and seem to use the activity solemnly as a way to assign costs. For the other dates, either the inbound activity is planned on one date (if the start and end date are the same for the activity, it can be seen as a normal activity) or the end date is taken (for activities starting with the number 3, indicating that they have a longer lead time).

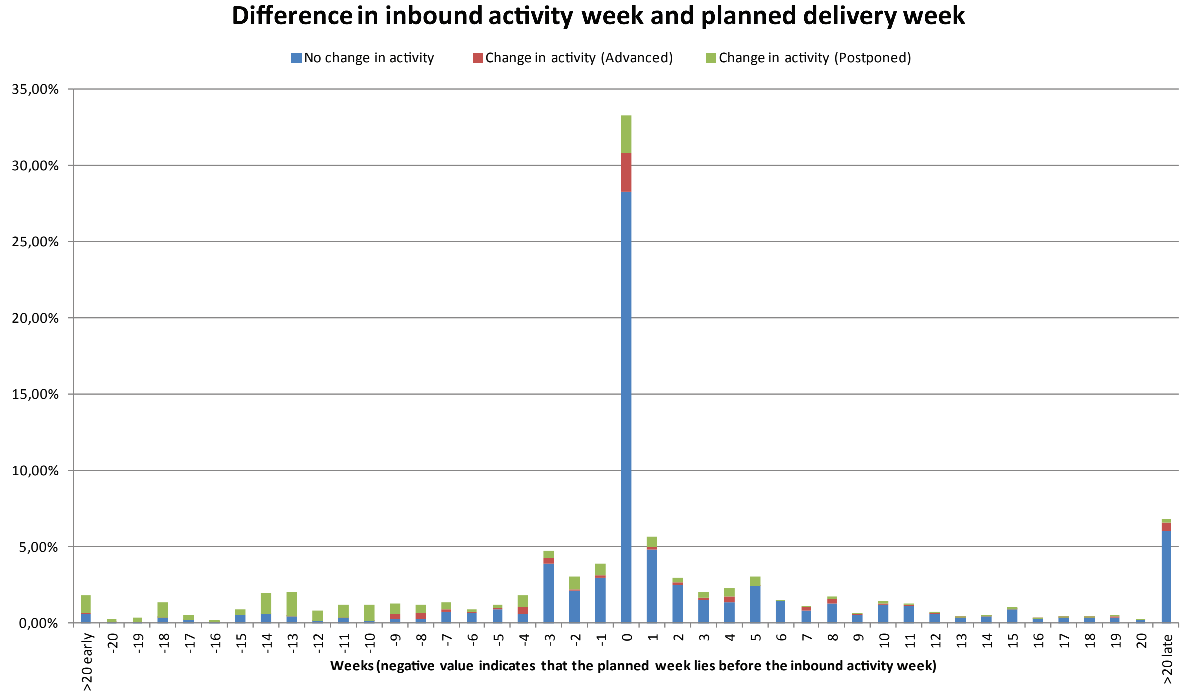


Figure 2.5: Graph of inbound activity date versus planned delivery date (arrived between week 32 and 51 of 2013)

Looking at the legend in figure 2.5 and 2.6, many activities change after being set. Although this often results in the goods being delivered in the right week, most of the items that are more than 10 weeks early are caused by activities being postponed, while the planned delivery dates are still on the old activity date. This causes problems in the central warehouse as the average time in the system increases and thus the amount of space used.

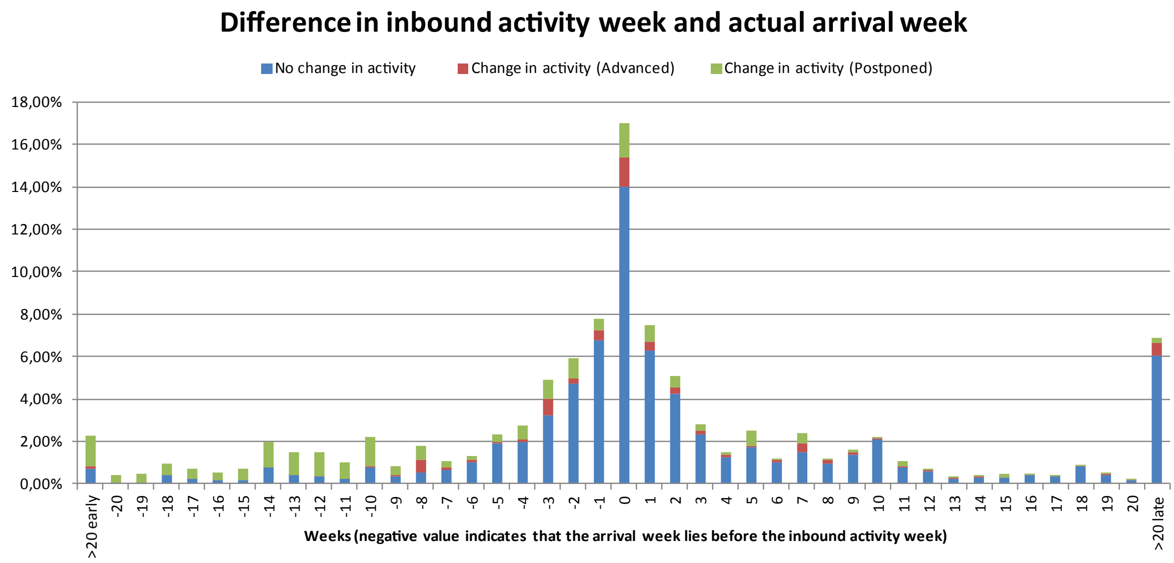


Figure 2.6: Graph of inbound activity date versus actual delivery date (arrived between week 32 and 51 of 2013)

To eliminate doubt within Damen Shipyards about other activities than 4.2.1, the graphs in figure 2.8 and 2.7 only depict activities in category 4.2.1 and that do not contain the letters NAL[2] in the activity description (and have start and end date of the activity the same and are received in the Central Warehouse by someone working in the Central Warehouse). Although this only accounts for 36071 lines, it gives a similar image.

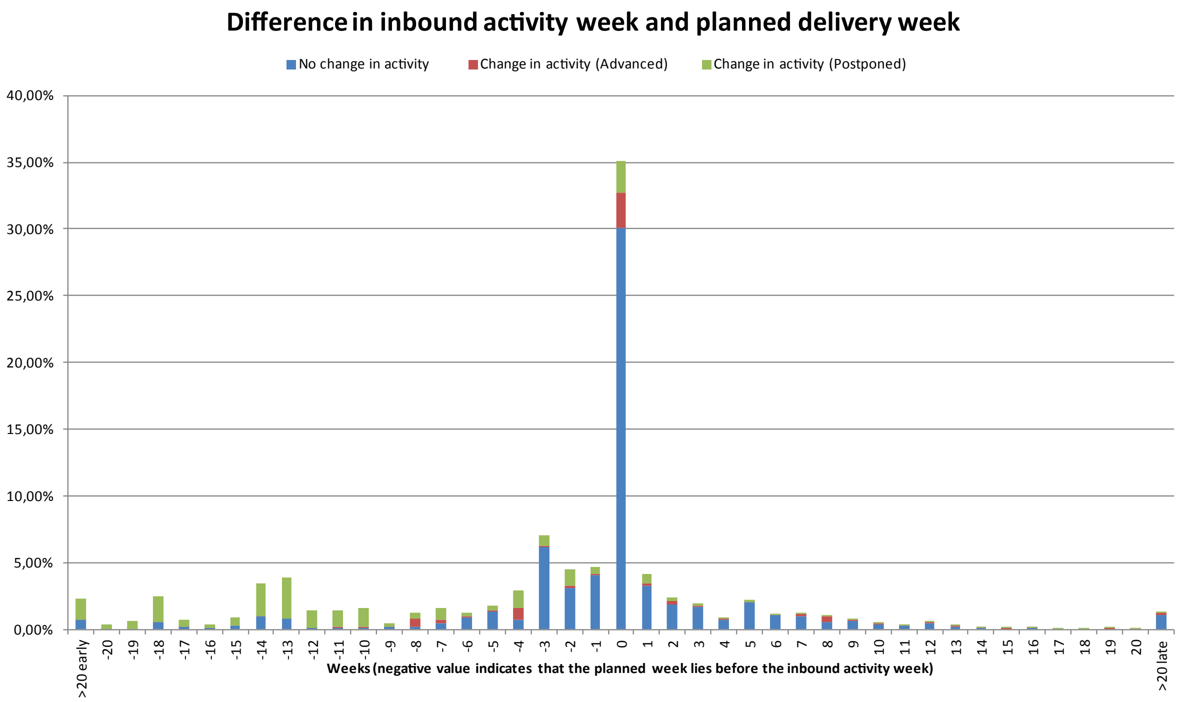


Figure 2.7: Graph of inbound activity date versus planned delivery date (arrived between week 32 and 51 of 2013 and only with 4.2.1 activity category)

[2]These letters indicate a backorder and are not planned in the same way

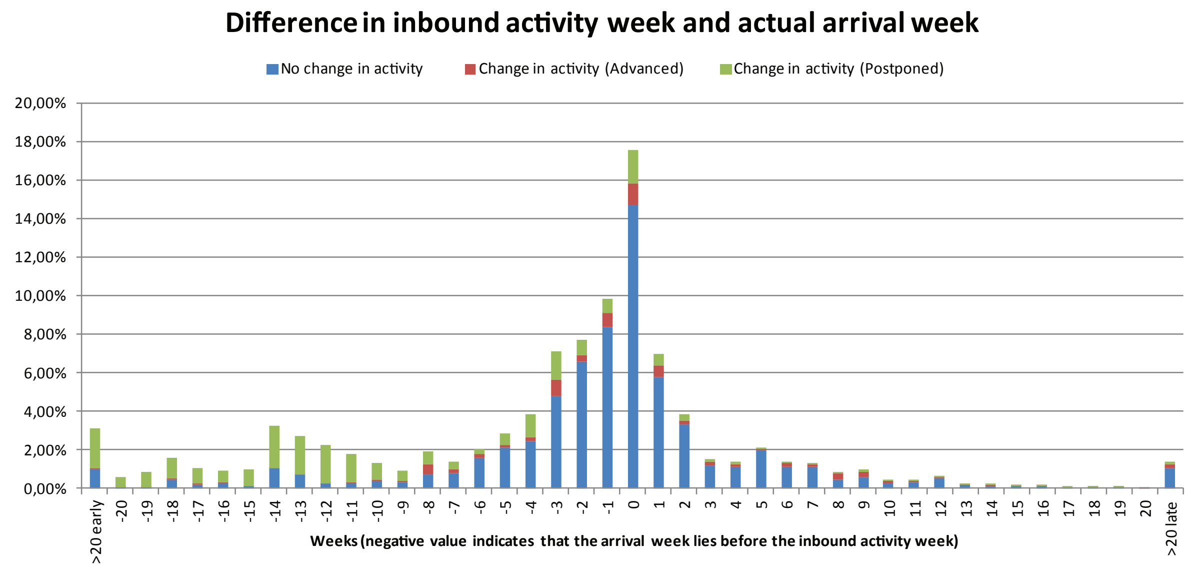


Figure 2.8: Graph of inbound activity date versus actual delivery date (arrived between week 32 and 51 of 2013 and only with 4.2.1 activity category)

2.4. How parts are purchased

The purchase parts function is handled by material coordination for spare parts and for rush orders or by the purchase department. They send out a wanted delivery date (based on the wanted receipt date on the purchase requisition order) out to the supplier and the supplier can respond with a promised delivery date. If no response is given, it is assumed that the supplier can deliver on the wanted delivery date. If parts are to be sent directly to the customer (not through Gorinchem), they are given a different delivery address in the purchase order. All these dates are variations on the previous date in the chain, causing the final variation of actual deliveries not to be around the activity, but around these planned dates (which are not linked to the demand in the warehouse anymore). This should be investigated further.

2.5. Handling Parts inside the central warehouse

This part of the supply chain lies inside the central warehouse. Data research shows that of what is picked for shipping, in a period from August 5^{th} 2013 until December 22^{nd} 2013, on average 800 lines a week come from the inventory. These items have not been purchased for a specific project, whereas the other 4300 lines per week have. The variation in these weeks can be seen in figure 2.9. The storage for inventory items is still situated at the old warehousing facility. The other storage (new warehousing facility) is only meant to store goods until they are shipped. In theory this should not be a long time. Data research also shows that on average, 5100 lines are received per week.

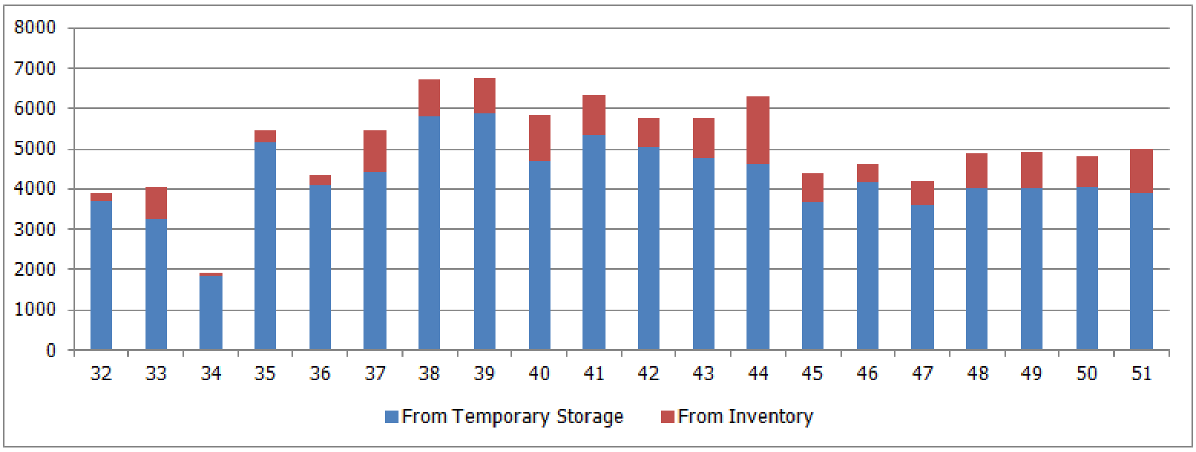


Figure 2.9: Division in source of picked items for shipping per week of 2013

The goods that are handled in the new warehousing facility are handled in 18800 m², which is divided into parts shown in figure 2.10. This should fit into 6700 m² (which is currently not empty as stated at the beginning of this research) by 2015 .

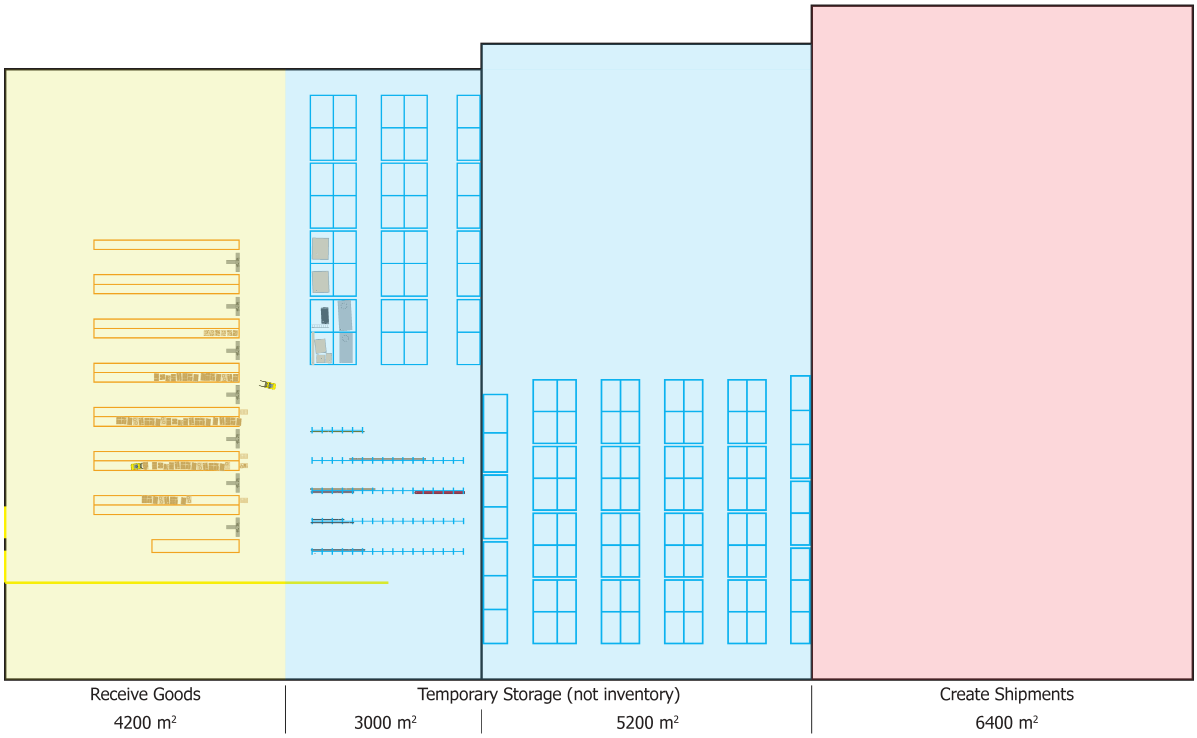


Figure 2.10: Space distribution in current central warehouse

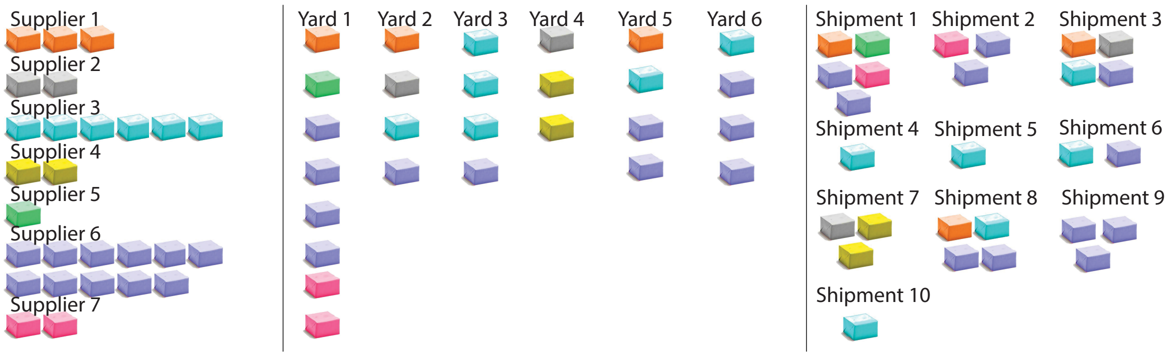


Figure 2.11: Illustration of the consolidation inside the central warehouse

To explain what consolidation means, figure 2.11 has been added. Goods are received from multiple suppliers and are then gathered for one shipment. This decreases the costs for transport.

2.5.1. Receive goods

Incoming goods are divided into categories. When inspection this process, it seems that the workload is not equal per worker and the amount of goods per checking lane also varies quite a lot. The categorization might thus have a negative effect on the throughput time and will be investigated.

2.5.2. Storage

From the last (registered) moment before storage (approval) until the first (registered) moment after storage (picking), the goods are waiting for an average of 8,67 workdays. This has been measured by taking all picked lines in week 32 to 51 of 2013 and cross-referencing the approval date. 73639 lines have an approval date, whereas 15382 lines come from inventory, 1619 were destined for Gorinchem and 3114 lines were purchase order transactions, all used by the services department. These have no approval date because this link disappears after goods are released to inventory. Also, if an arrival and approval date are present, the time between these should be more than five seconds, otherwise this would indicate automated processing. In the new warehousing facility (in IFS applications indicated with the 'M') there are goods with a total value of 9.17 million euro. All these goods have been placed into the warehouse in IFS Applications and have not been set as 'sent'. 4.65 million euro worth of goods have a location, whereas 4.52 million euro worth of goods have been reserved for shipment, after which they will not change status until they actually leave the premises. This means that 4.52 million euro worth of goods is situated somewhere in or around the warehouse, but Damen doesn't exactly know where (often on the outbound side). This does not include items that are not yet approved. Before approval, the value of the item is not set in the inventory (so inbound in figure 2.12 doesn't account for any inventory value).

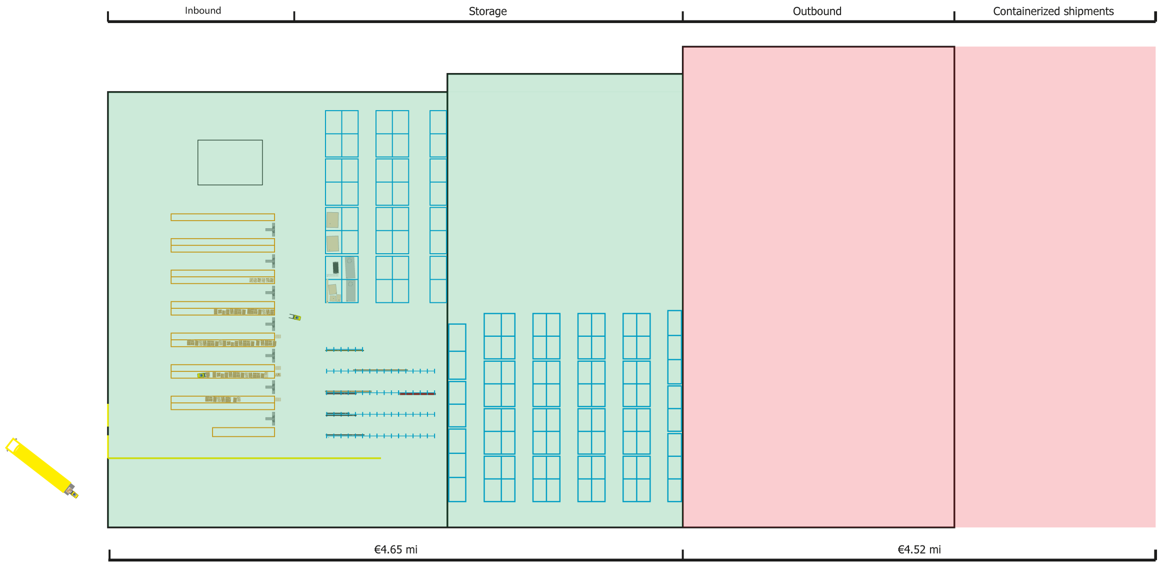


Figure 2.12: Inventory worth

If Damen wants to store their goods for longer amounts of time, they should look at it as such. Goods that are not to leave within a certain amount of time should be put into efficient storage, so that the amount of square meters in the warehouse is better utilized.

2.5.2.1. Quantity

The amount of items in storage can be expressed with the help of Little's Law (eq. 2.1), by taking the average amount of input per week and multiplying it by the average amount of weeks it is in storage. If the situation would be as planned, this would never be longer than five days, the planned situation is, however, not close to reality.
As has been stated in section 2.5.2, the average amount of workdays between approval and picking is 8,67 workdays and the average input per workday is 1020 lines. This means that the amount of lines continually in storage is (according to Little (1961)):

$$1020 \cdot 8,67 = 8843,4$$

The average amount of days between approval and picking excludes the inventory items, which are not administered as well as the project items, but of which it can be expected that its time in the system is longer.

2.5.2.2. Division

The goods in storage are divided into groups according to size (large goods, long goods and others). This makes the picking of the items easier, but creates another problem. If in one week, no items for a certain project arrive, there is still a rather large section that cannot be used although it is empty. Long goods are stored in special racks and must be moved with a special fork lift truck. Large goods (or heavy goods) cannot be placed in the normal racks, because these would outweigh the maximum weight for the racks. Other goods can be placed in the normal racks up to a certain height, depending on the height an average fork lift truck in the central warehouse can reach. Also, because all goods are palletized, single goods will be placed on a pallet and take up more space than needed.

2.5.2.3. Examples

To illustrate the poor use of storage space, three examples are shown in this section with the help of images. Their viewpoints are shown in figure 2.13.

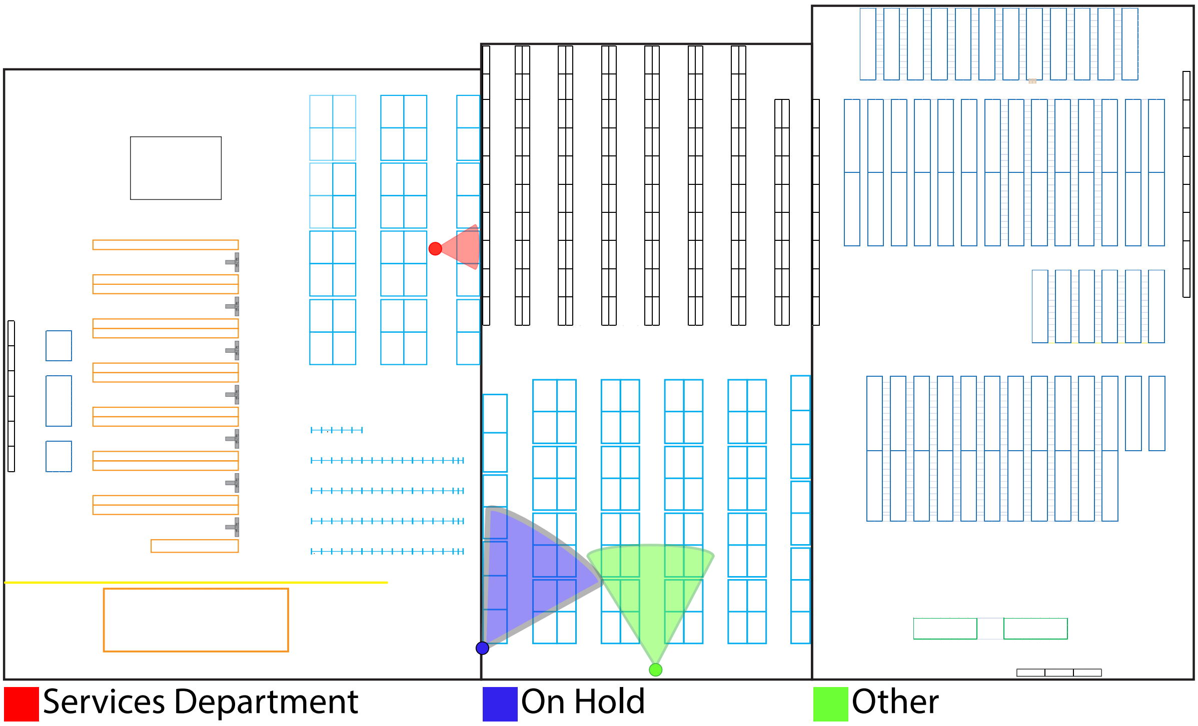


Figure 2.13: The viewpoints of the examples in this section. The names in the legend refer to titles in this section.
Source: Author

`Example: Service Department`

Initially, the services department was not a big issue for reducing in size. They seem not to have all their affects in order, which can be concluded by symptoms that surround that department. All their racks are much fuller than other racks and more problems and exceptions seem to be surrounding this department. It seems that their performance measurements are defined by their own section and in a very different way than all other goods that come into the central warehouse. Initially all this was not a problem, because they had only a limited amount of space to use for their goods. Recently, they got three times the space they had and they are certainly using it in a way that makes it a large issue when returning to the smaller warehouse. Examples are added below in figure 2.14, with the date the photo was taken.

Figure 2.14: Example of disadvantages of new way of working for services department
Source: Author

Figure 2.14 shows a method of working that uses the available space quite inefficiently. When something arrives for a project, a whole section is reserved for that project. Although this could save time, in certain cases it uses far too much space. While the process is as bad as it is, this could go on for weeks. The worst part about this is that nothing will be sent until the last package arrives at the warehouse, without pressuring the incoming deliveries. By getting more insight into this department, the performance check (or the lack thereof), can be improved. The only reason that department seems to exist is for putting new boxes around spare parts, so that the customer will not get to know the manufacturer. Which is often not very effective because many parts have a logo embossed in them. This combined with the lack of profit for this department makes the department of this size arguable.

`Example: On Hold`
Figure 2.15 shows the effects of goods that are delayed for whatever reason. These are then called 'on hold', and will be shipped when they have been cleared from that status. This could take weeks or months and in this picture, there are goods that have been there for a long time, and goods that have been there for a very long time since they are there in the first picture and still in the last. This is no exception and should be investigated further.

Figure 2.15: Example of slow flowing materials at Damen Shipyards

`Example: No Problems`
The goods in figure 2.16 are not put on hold or delayed. Still on the right side there are goods that are present in the picture made on the twentieth of January, and have not left on the fourth of November. This indicates that the planned period of less than five workdays in storage is not always met. Goods that stay in storage for extended periods of time have a great effect on the space usage and whether or not their space usage is efficient is arguable.

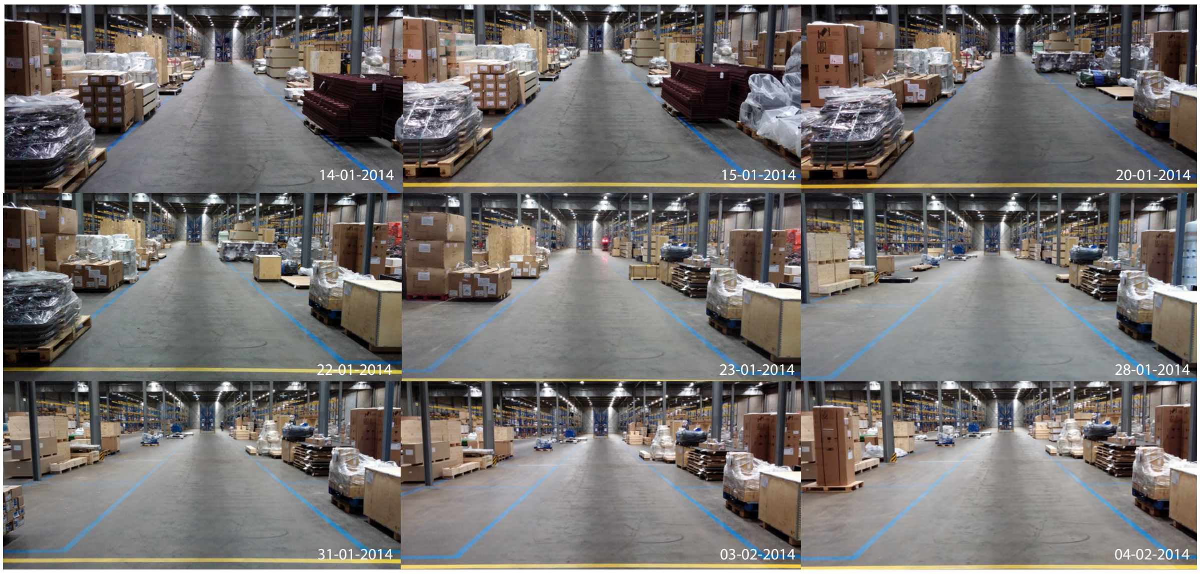


Figure 2.16: Example of normal flowing materials at Damen Shipyards

2.5.3. Create shipment

Although most space is taken up by storage, the space used for the outbound process almost equals the space in the other warehouse. The slowness of the handheld terminals frustrates the workers and has a great influence on the time in the system and thus the space efficiency. This should be investigated.

2.5.3.1. Damen Technical Cooperation

There is one type of shipments that is growing within Damen Shipyards, it is called DTC (Damen Technical Cooperation). It can be seen as a boat in the form of a construction kit for the customer. It needs more work (three weeks for creating the shipment) and more space, combined with the fact that customers often want to come and inspect the materials. This causes a clog in the system if not handled differently. This will be discussed and improvements will be given later on in chapter 8.

3
Analysis Delft System Approach

The Delft System Approach (Veeke *et al.*, 2008) will be used to analyze the problem sketched in chapter 2. First the process will be depicted as a black box, which is defined by in 't Veld (2002, chapter 3) as a system or subsystem of which the internal elements and relations are not yet known to the researcher, or that are not (yet) studied by the researcher. In this stadium, only the inputs and outputs of the box are watched. Then the black box will be opened to reveal other black boxes that lie one aggregation layer deeper and give more information about how the process works. This can be repeated as many times as needed to pinpoint relevant issues in the warehousing function of Damen Shipyards Gorinchem.

3.1. The black box approach to the central warehouse

The first black box is shown in figure 3.1. This is a steady state model of the warehouse. Whatever could change about the warehousing function for Damen Shipyards Gorinchem, this will stay a representation of what happens here. Inside this black box, everything that comes into the central warehouse and thus takes space in the central warehouse is transformed to outgoing goods. The system boundary for the flow of goods is put around the central warehouse since this research is about space usage inside the central warehouse. Only the processes directly influencing the inputs or outputs will be regarded in addition to this. The most important requirement is the timeliness of the outgoing goods, this is also what is seen as the most important performance indicator. How a requirement for more efficient use of space can be handled with changes in the processes will be researched, but is currently no real requirement for the warehousing function.

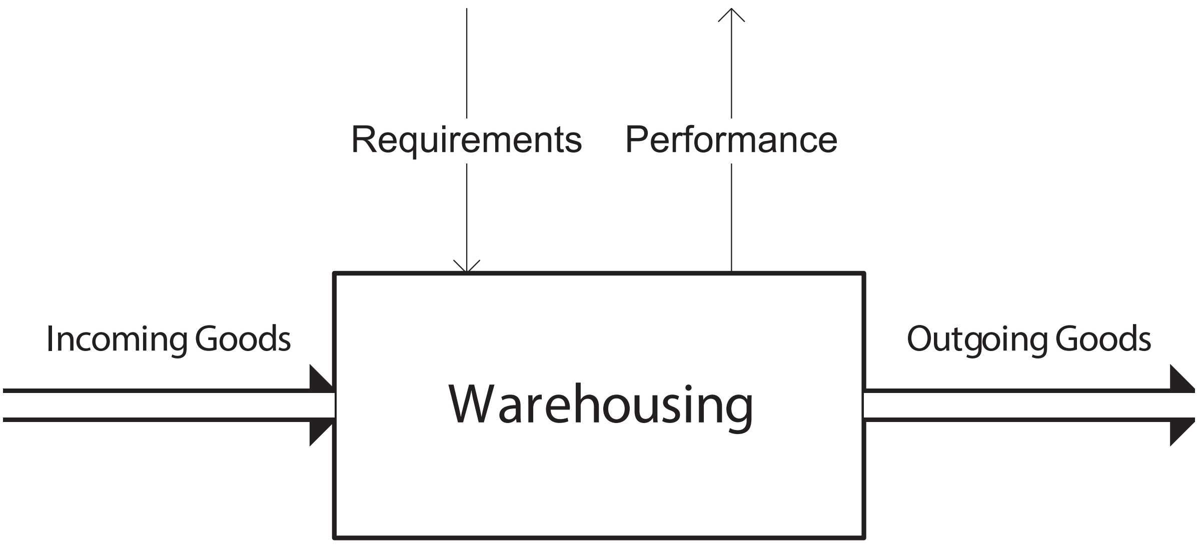


Figure 3.1: Black Box approach to warehousing

To be able to pinpoint the issues of the warehousing function on this level, only the inputs and outputs can be analyzed.

The input stream consists of goods from suppliers that are ordered for the construction of a boat or for the inventory. The orders are handled separately but interact with the central warehouse. The order flow will be researched if relevant to the goods through the central warehouse.
The output stream consists of consolidated goods for the customer with different modes of transport. The function 'warehousing' transforms the input to the output with certain requirements that can be led down to timeliness of deliveries.
To analyze the space usage and the reasons for this, more details are needed. To get these, the model is opened up to find what lays one aggregation layer deeper. The next aggregation layer has been depicted as a process performance (or PROPER) model. This model is introduced by Veeke *et al.* (2008, chapter 5) and they state it contains at least three aspects:

1. The "product" as a result of a transformation.
2. The flow of orders; without customer orders no products will flow. In this flow, orders are transformed into handled orders.
3. The "resources" (people and means) required to make the product. To make use of them, they must enter the system, and they will leave the system as used resources.

The results of the transformations are delivered products, handled orders and used resources.

This model is used to analyze the central warehouse for Damen Shipyards Gorinchem further because it allows for the use of different aspects in one model and this connection appears to be of importance from the previous chapter. The important resource is 'space', because it is leading in this research. The introduced PROPER model is shown in figure 3.2. By looking at these aspects and their interaction, the use of space can be analyzed (by looking at the resource flow) and the cause for the high expected time spent in the system (W in equation 2.1) can be looked for in the connection with the order flow.

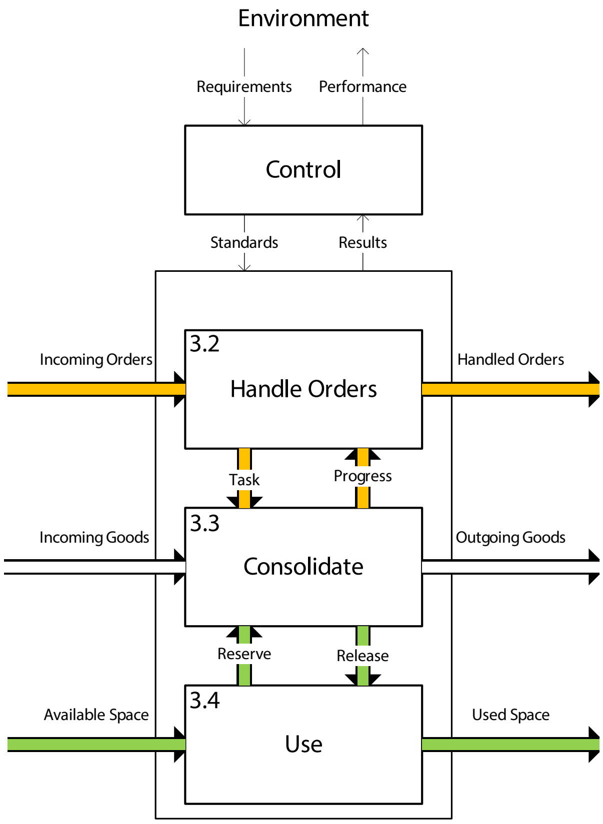


Figure 3.2: PROPER model

The three aspects for Damen Shipyards Gorinchem are orders, goods, and space. The space in this case is a resource that is used to process the goods stream and the orders form the tasks for the consolidation function, these are shown as thick arrows between the functions in figure 3.2. The control function translates the requirements into usable standards in the process and checks the results to see if the performance meets the requirements, these 'data' streams are shown as thin arrows. To find out what causes the use of space, its interaction with the consolidation function will be analyzed in section 3.3. To find out how the progress is translated to results and what causes the average time spent in the system by incoming goods, the order handling function will be analyzed in section 3.2. The 'use' function that makes use of the resources will only not be handled separately since it is not planned or administered within the central warehouse.

3.2. 'Handle orders' as a system

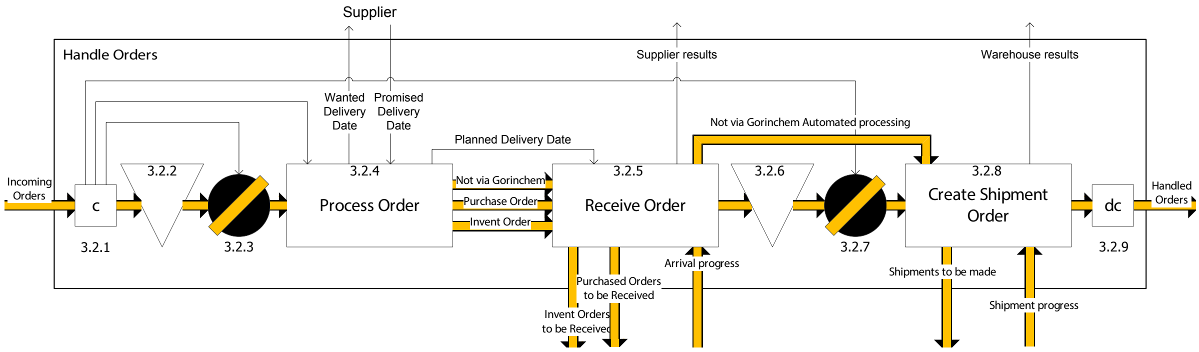


Figure 3.3: Zoomed in on function 'handle orders'

In figure 3.3, the order flow is shown. This is a steady state model. In it, the 'warehouse results' are one of the main points on which the performance of the warehouse is measured. What causes the bad results can be found out when looking more closely at what happens inside the order flow by zooming in again. The names of the functions (that are not named in figure 3.3) are taken from Veeke *et al.* (2008) and are explained in the figure (from left to right).
The 'incoming orders' are orders that are specified and approved within Damen. To process them further, they need to be put into a form that is understandable further on. This is called 'encoding' in the Delft Systems Approach (the square containing the letter 'c'). In this case it means that the order (e.g. a boat), is split into several blocks or zones based on the building sequence of the yard and on on the amount of time it takes to process them further. The output for this step is (the orange arrow on the right side of the block) the orders, cut down into processable parts and at the top it gives signals (or dates) on which certain actions must be taken.

The divided orders will be processed in their planned order. The orders that are not yet processed are queued in a buffer, indicated with the triangular shape. The orders stay in this buffer until the planned start date (coming from the encode function), then the tap (the black circle with the rotated orange line) will let the first part through to be processed. The zones or blocks will then be drawn, translated into parts, and purchased or reserved from inventory, summarized in the function named 'process order'. Certain orders will be sent directly to the customer, without going through the central warehouse in Gorinchem, the transport will then be arranged by Transport Coordination and the order will be automatically processed and booked out of the system. The planned delivery date is used as the most accurate estimation of when the goods are to come in. But as can be seen in figure 3.4, it is far from accurate.

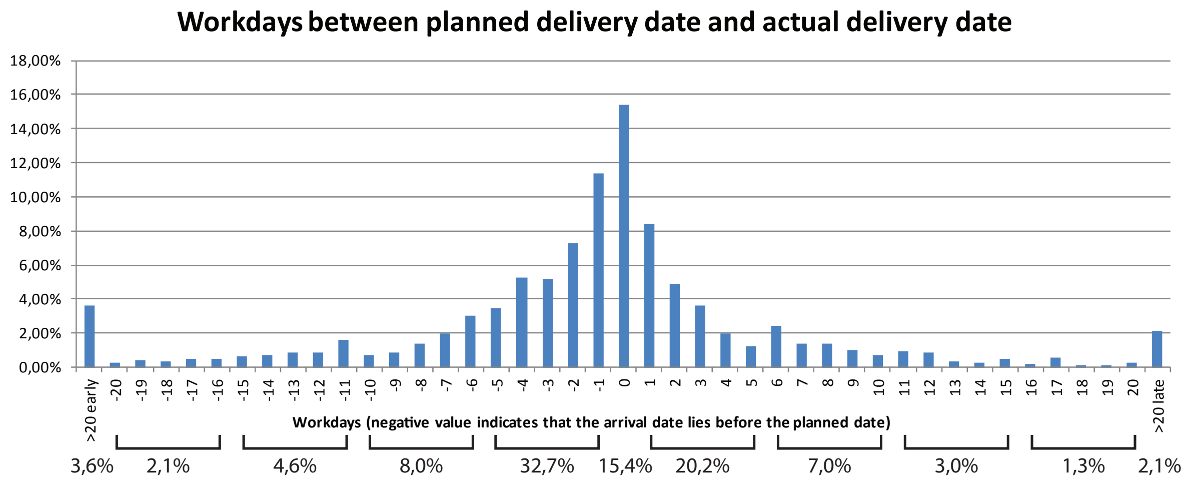


Figure 3.4: Graph of planned arrival date versus actual arrival date (arrived between week 32 and 51 of 2013)

The central warehouse hopes to plan their capacity on the amount of planned lines in a week, but even when the planned week is used as a prediction of the work load, it will be far from the truth as can be seen in figure 3.5.

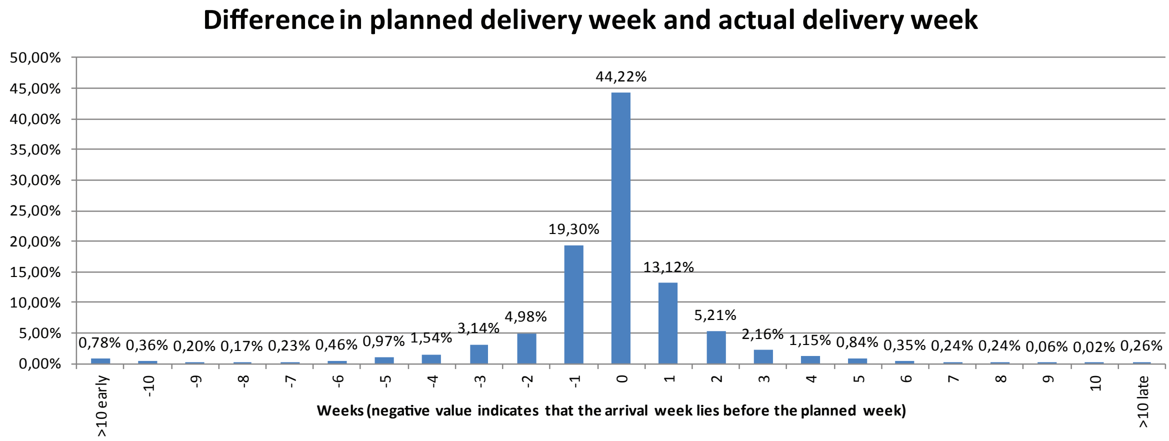


Figure 3.5: Graph of planned arrival week versus actual arrival week (arrived between week 32 and 51 of 2013)

To find out where this large deviation comes from, this function will be opened in section 3.2.1.

The remaining orders will have to be received in order to continue the order flow. Because all goods are marked as 'to be received' when they are received by the incoming goods section, Damen can verify if the promised delivery date is met. This has been unreliable data in the past because the goods used to be unloaded before they were registered and thus there could be days between the actual arrival and the registered arrival. This has changed since the move to the new location; now goods are all registered before they are unloaded and are given the status 'to be received' and an arrival date and when they are checked they get the status 'received' and an approved date. The only feedback to the suppliers is when they are too late (they will then receive a reminder). Early deliveries are not seen as an issue because "then at least we'll have it".

With the arrival progress marked as 'received', the order goes into another buffer (just like the goods will be stored in the warehouse) where it waits until the tap is opened. This signal (indicated with the thin line) is given on the start date of the activity (normally indicating with an activity starting with the sequence 4.2.2). The tap then flushes the buffer of all goods that have arrived for that particular activity and goods that should have been shipped with an earlier activity. Note that here, the original activity dates are used, whereas the previous steps use translations of this date (with a margin). The orange stream leaving the top of the 'receive order' function is the order stream of goods that do not physically go through the central warehouse, but go directly to the customer. Even though the streams are separated, they are registered in a similar way making the data analysis more of a challenge. The difference is that they do not have to wait until the start date of the outbound activity. In the function 'create shipment order' the shipment and its picklists are created and the assignment to gather all these items is passed on to the material flow. When the shipment is ready, the order can be processed further. The date that the shipment is finished should be before or on the end date of the activity. The warehouse results reflect the ability to do this. At the end of this flow the goods have to be made usable for the customer, the order has to be decoded (indicated with the square with the letters 'dc' in it). This means that a packing list is added and that the transport is arranged.

3.2.1. Zoomed in on the 'process order' function

Figure 3.6 shows the aspect of orders that are for a newbuilt boat (and thus not for spare parts or for repair parts). The functions that can be found inside this function will be handled from left to right.

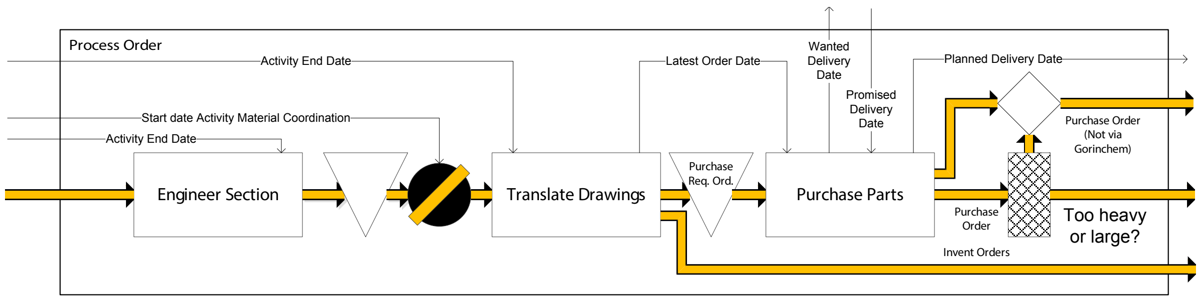


Figure 3.6: Zoomed in on function 'process orders'

Engineer Section

The batches of work come into the 'engineer section' function. This function transforms the input (specified parts of the order) to engineered sections in the form of drawings.

Buffer

The drawings are gathered in the buffer until certain batches are complete and ready to be sent to material coordination.

Tap

The material coordinators start on the date the activity is set to start, unless drawings for the previous (or this) batch are not yet finished.

Translate Drawings

The material coordinators have two weeks to extract bills of materials for the drawings and then either:

- Make a purchase requisition order that they handle themselves. This is done for spare parts and for rush orders
- Make a purchase requisition order that is handled by the purchase department. These are divided into parts that have a lead time longer than eight weeks and other parts.
- Order the parts from the Damen inventory.

Buffer (Purchase Requisition Orders)

The requisition orders end up in a buffer and are handled sorted on latest order date (wanted receipt date minus the expected lead time in the system).

Purchase Parts

As stated in section 2.4, the 'purchase parts' function is executed by material coordination for spare parts and rush orders and the other orders are handled by the purchase department. For all orders, a purchase requisition order is made which creates a demand that can be filled with new parts, inventory parts or 'surplus' parts, which are leftovers from other projects.

The exact reasons for this and possible solutions will be discussed in chapter 5.

Filter

When initially the 'purchase parts' function decided to send parts through Gorinchem, the transport coordinators can still arrange for them to go directly to the customers if they are expected to be too heavy (more than 4000 kg) or large (more than ten cubic meters). This step is handled in a manner very similar to the normal procedure through Gorinchem, they are marked as arrived, approved, are put into a shipment and are eventually marked as 'delivered', which makes this a step that is hard to filter out in the system.

3.3. The 'consolidate' function inside the central warehouse as a system

The function 'consolidate' as seen in figure 3.2 transforms the incoming goods into goods fit for shipping. This means checking and labeling them on arrival and consolidating the different goods into shipments for each customer. A closer look into the function 'consolidate' gives the steady state model in figure 3.7. The stream from the 'use' function in figure 3.2 is included to get the reasons of space usage insightful and the stream from the 'handle orders' function is included to show important communication steps in this process. The subsection numbers that are handled correspond to the numbers in figure 3.7.

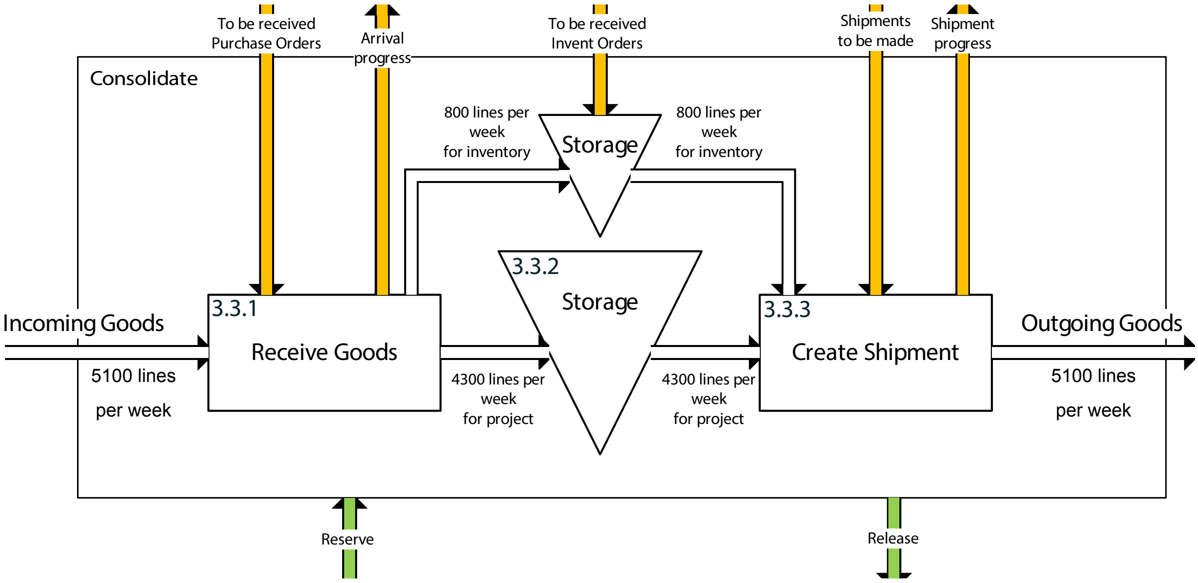


Figure 3.7: Zoomed in on function 'consolidate'

The upper storage is meant as an inventory and contains items that can be reserved by various parties within Damen Shipyards. This storage is still situated at the old warehousing facility.
Reflecting on how to go back to a smaller warehousing facility, the problem in figure 3.7 is that too much space (indicated with the green arrows) is used for the process and that the targets set by the order flow (indicated with the orange arrows) are not sufficient to create a good performance.
To get a better grip on the causes of these issues, the functions in figure 3.7 will be opened further in the coming subsections. By doing this, the causes for use of space can be further analyzed. The performance will later be analyzed by opening the 'handle orders' function in figure 3.2. The warehouse that is used now has a floor area of 18800 m^2, and is divided as can be seen in figure 2.10. The inventory items (upper storage in figure 3.7), are now stored in a section of the old warehousing facility.

3.3.1. Zoomed in on the 'receive goods' function

As can be seen in figure 3.7, incoming goods are divided into categories. The categories that are now considered are the items for the inventory and the other lines. The general way of handling the receipt of goods, valid for all categories, is shown in figure 3.8. How Damen can perform this function with less space is discussed in chapter 6.

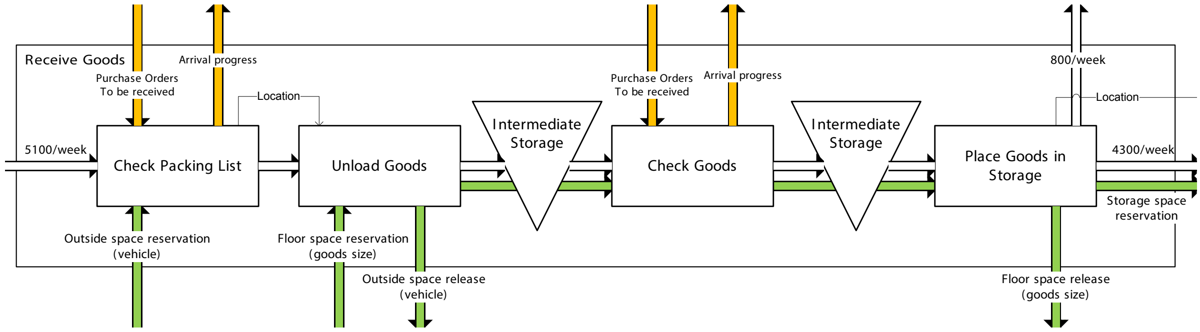


Figure 3.8: Zoomed in on 'receive goods'

Summarized actions that occur inside the functions in figure 3.8 are as follows.

Check packing list
When the driver arrives, the packing list is checked to comply with the order. If it is a partial delivery, only those lines delivered are set as arrived. This is done so that the arrival date is more representative of the supplier's performance. During this check, some outside space is reserved for the delivery truck.

Unload goods
When the packing list has been checked, a fork lift truck driver is given the task to unload the goods. The goods are then placed in arrival lanes (where some space will be taken, indicated by the green arrow pointing inwards) along with the arrival sheets. These will be used in other steps to identify the goods. When the delivery truck is unloaded, the space reserved by that truck will be released.

Intermediate storage
The goods are in the arrival lanes and every lane is treated as FIFO (first in - first out), meaning that the goods are checked in the sequence they are placed in the lane. This section currently reserves a total of X m^2, assuming that it is never filled more than the space reserved. This is done by outlining the section.

Check goods
The goods are checked at workplaces, at which the packages are opened, checked for quantity, and labeled. They are then put in a buffer meant for checked goods.

Intermediate storage
Goods are stored here until the quantity or volume justifies a trip with a forklift truck to storage.

Place goods in storage
Goods are placed into storage based on the country it is destined for. The places in the storage are marked with barcodes to enable quick processing. The amount of space reserved here is different from the amount of space reserved for checking. This is caused partly by goods being placed in racks (making more efficient use of floor space), and by the fact that every item must be placed on a pallet, causing small boxes to take up too much space.

3.3.2. The buffer (Storage)

The amount of storage space reserved per order line has to decrease in order to be able to return to the previous warehousing facility. How this should be done will be discussed in chapter 7.

3.3.3. Zoomed in on the 'create shipment' function

To find out why this step takes so much space, the 'create shipment' function in figure 3.7 has been opened in figure 3.9. This concerns the average process, another important stream is the creation of DTC (Damen Technical Cooperation) shipments. This will be handled separately.

3.3.3.1. Normal shipment

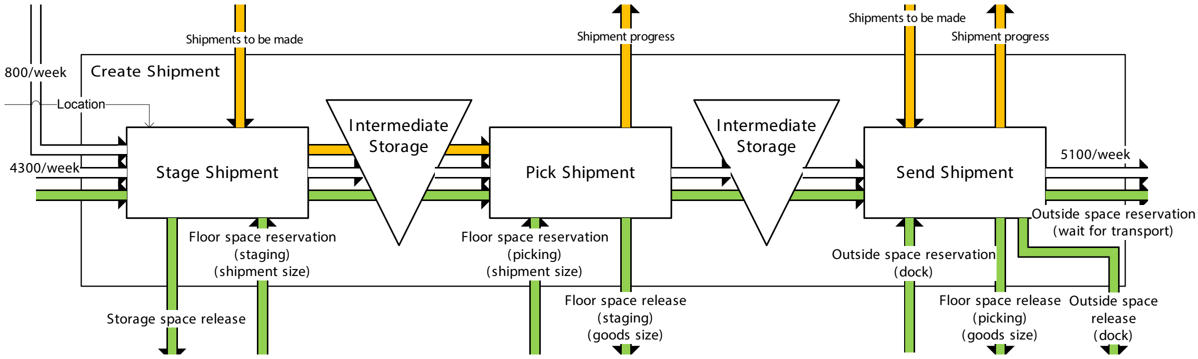


Figure 3.9: Zoomed in on 'create shipment'

Summarized actions that occur inside the functions in figure 3.9 are as follows. The way to consolidate the shipments with less space is discussed in chapter 8.

Stage shipment
With a picklist, shown on the handheld terminal, the locations of the goods to be shipped are shown. Goods are picked with a fork lift truck. This releases some storage space as is indicated by the green arrow, but it will reserve outbound space which is less efficient because there are no racks to utilize height.

Intermediate storage
The goods are put into an intermediate storage (staging area), where the items will lay until they are further handled. When the first item is put into the staging area, an area the size of a twenty-foot container is reserved.

Pick shipment
When the staging area (intermediate storage) is sufficiently filled, the items go into a 'handling unit', often a wooden folding crate. This action is called 'picking' at Damen Shipyards. Every labeled item is scanned and put into this crate with the handheld terminals. The space used for the handled goods is then released from the staging area and space for picking is reserved.

Intermediate storage
The handling units are stored until they are ready for shipping in an intermediate storage. Again, when the first item is put into this picking area, a tweny-foot container sized area is reserved. Although goods are placed in another intermediate storage when they are put into the shipping unit, this is depicted as the same intermediate storage because no additional action is taken.

Send shipment
When the shipment is ready, in the case of containerized transport, the handling units will be put into containers with the support of a wooden body that is custom built by 'Schijndel Industriële Verpakkingen'. To be sure the right content go into the container with the appropriate weight distribution, a handwritten note is used with the handling unit numbers, dimensions and weight. When all items are in the container, a packing list will be made for the customer.

Progress
Throughout the process, progress is registered by the use of handheld terminals with Radley software installed on them. This middleware[1] communicates with the database and gets relevant information and changes it if needed. This process is very slow. The measurements shown in figure 3.10 are used to convince management to invest in improving the system and soon this time will be reduced to mere seconds. This could easily save 40% time for outbound as the depicted time is only for the picking, the staging takes just as long per step, but can be done per pre-grouped batch in stead of per part. Also, the lost time is more than only the time that you should wait for the system, because the work pace is

[1]Middleware is computer software that provides services to software applications (IFS) beyond those available from the operating system (Wikipedia)

disrupted severely. If the administrative step here is faster, the work will be about putting goods into seaworthy packaging in stead of administrating what is done. This step is even more futile when it concerns unopened crates. Some supplier deliver crates that are ready to be sent to the customer. In stead of directly sending it to outbound, it will be registered per part and all the stickers will be put on the outside of the crate as a bundle. By doing this, the picking step will not add any value, but take tedious amounts of time that are often spent in the cafeteria.

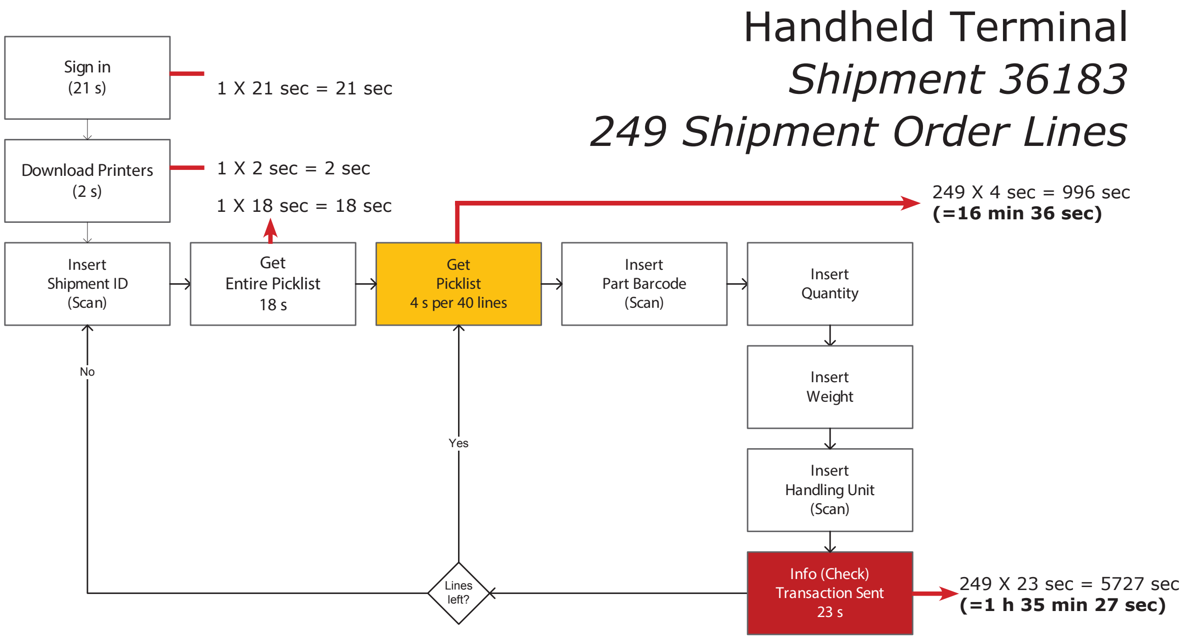


Figure 3.10: Visualization of the Radley performance

3.3.3.2. Shipments for Damen Technical Cooperation

The Damen company website[2] states the following about Damen Technical Cooperation:

> Damen Technical Cooperation enables our customers to build their Damen vessel locally, anywhere in the world. We provide our clients with a prefabricated shipbuilding kit and can, on request, combine this with expert assistance, training and backup.

In the central warehouse, this implies extra work in consolidation, since the 'kits' should be as drawn in the building instructions. The most space is used for this when the customer wants to inspect the goods before they are shipped. To accommodate the building according to the instructions, all goods are sorted according to their 'function code' (which indicates for what part of the ship it is meant) and laid out on the floor so that all goods can be checked by the customer. It has often happened that the date the customer would inspect the goods was postponed multiple times, leading to a large amount of space being wasted for no reason. Because this department is very profitable and growing in size, this should be improved to maintain quality standards. Although a part of the material flow might avoid the central warehouse in Gorinchem in the future, management expects that the consolidation for the DTC-projects will remain in the central warehouse. This makes it a point of interest for this research and it will thus be investigated.

[2]This information can be found on the url: http://www.damen.com/en/services/startup/technical-cooperation

4
Problem definition

4.1. Initial research question

The original setting for the research was put by Damen as:

> The Central Warehouse (CW) in Gorinchem (the Netherlands) forms a central hub in Damen's global supply chain: here, the majority of the materials are checked, registered and consolidated before being shipped to the specific yards. The processes are challenging, as it is characterized by (very) short lead times; a large variety in materials; and a variety of destinations and the accompanying requirements. In the near past, Damen's CW was struggling to keep up with the growing material flows. As a result, late and incomplete shipments were pushing the organizations flexibility to the limits. To relief the organization, the CW will in 2013 temporarily move to a larger location. The general management has however stated that in two years (2015), the warehouse will move back to their currently facility. In order to prevent the problems from reoccurring in the future, the organization and flows through Damen's warehouse urgently need to be revised.

The facility that is in use since July 2013 offers 18800m^2 whereas the previous facility, to which Damen Shipyards Gorinchem wants to return, only offers 6700m^2. Because the space is available, Damen is gradually using more and more of it, causing the return to become increasingly difficult. What causes the need for this amount of space and what can be done to decrease this need? And how can this be achieved by July 2015? This leads to the initial research question:

'How can Damen Shipyards Gorinchem improve the efficiency of their current space usage by 64% in order to return to the previous warehousing facility before July 2015 ?'

4.2. Division into categorized subquestions

To explore the current space usage, the problem has been split into four parts, all adding inefficiency to the space usage. The four parts are shown schematically in figure 4.1. The choice for this split is explained in the coming sections as well as their inefficiency in space usage. The sections will be concluded with a subquestion into which the research question is divided and a reference to the chapter in which the subquestion will be answered.

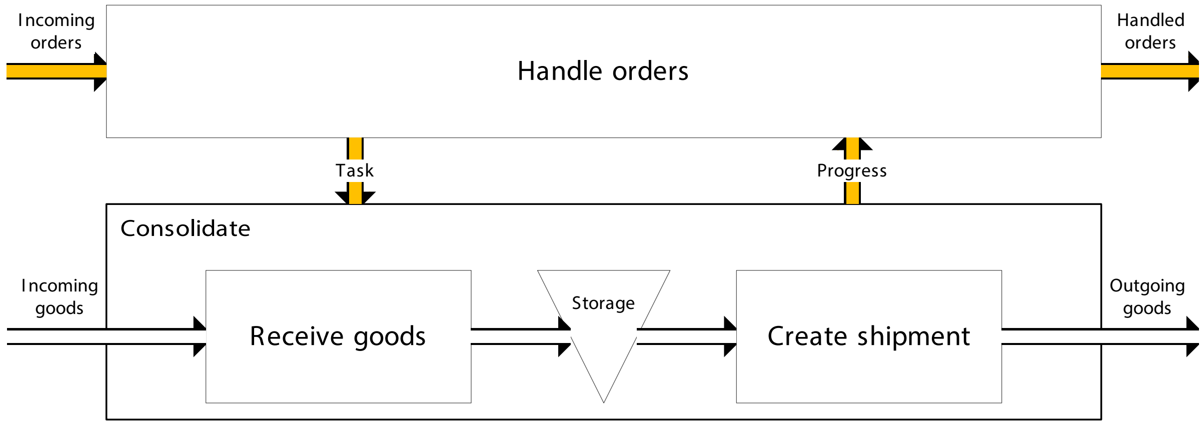


Figure 4.1: Main contributors for inefficiency in space usage

4.2.1. Handle orders

The function 'handle orders' arranges the incoming goods for the 'consolidate' function and thus is responsible for the λ in Little's Law (equation 2.1 on page 8) and more importantly, responsible for a large part of the average time in the system (W in Little's Law). This makes this function responsible for a large part of the inefficiency of the space usage which makes it important to explore.
The inefficiency has already been pointed out in section 3.2. As can be read there, the function 'purchase parts' in figure 3.6 is unable to process the desired delivery date so that the actual delivery date is the same. The fact that the date the planning department puts into the system is only in the same week as the actual delivery date in 17% of the cases (see figure 2.6), causes much inefficient use of space (7,8% is delivered in the week before the wanted week and 35,2% is even earlier). The reason for that this causes inefficient use of space is that early deliveries increase the time in the system (W) and thus the average amount of items in the system (L in equation 2.1), and late deliveries create inefficient shipments (when shipped separately or sent via air transport) and can even delay shipments if the items are crucial for the building process, again adding to the time spent in the system (W). Can this solely be put as 'bad suppliers performance', or is Damen also not functioning properly? And how much efficiency in space usage can be won here? This leads to the following subquestion:

'How much more efficient can the space be used if incoming goods are delivered in time and how can this be reached by changes in the organizational structure?'

This will be discussed in chapter 5: Just in time on page 33.

4.2.2. Receive goods

The function 'receive goods' is one of the three parts in which the 'consolidate' function is divided. It is a necessary part for this system, but should be done with less space in order to return to the previous warehousing facility. In figure 4.2, a simplified version of the function 'receive goods' is shown. In this figure, the main functions that are needed to receive the goods are shown. After the packing list is checked, the goods will be unloaded and put into checking lanes (which are defined as intermediate storage). The goods will be in this lane until the dedicated person for that lane has handled all earlier arrivals (the goods are handled first in - first out per lane). The choice for lanes are chosen by the one that checks the packing list in accordance with the forklift truck driver and based on the amount space that is free on a checking lane. The need for intermediate storage is caused by differences in processing speed. For the first intermediate storage this is the difference between the unloading speed and the checking speed and for the second intermediate storage this is the difference between the checking speed and the frequency with which these items are then put into storage.

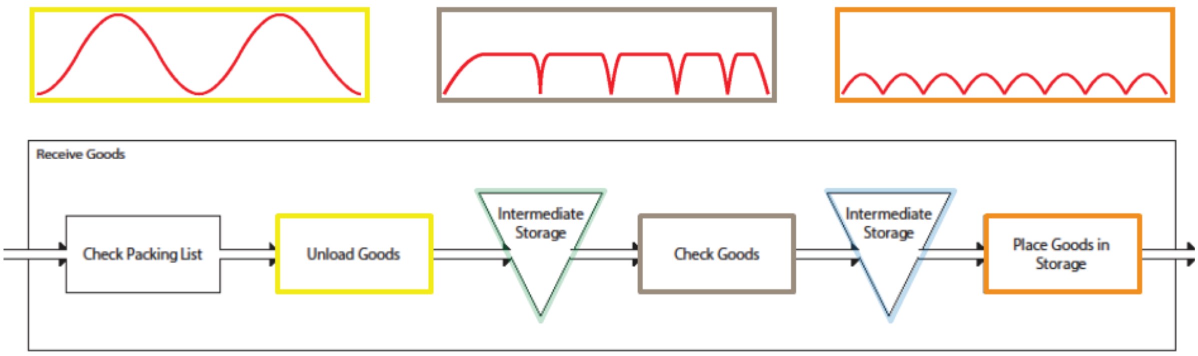


Figure 4.2: Visualization of functions that are not fine tuned to each other

Another issue is that when the flow of incoming goods is very high, the reserved area for this function might be too small, whereas it is much too large when the inflow is very low. The issues together lead to the following subquestion:

'How much more efficient can the space for incoming goods be used by changes in the method of work and how can this be accomplished?'

This will be discussed in chapter 6: Handling Incoming Goods on page 41.

4.2.3. Storage

The buffer for goods (called 'storage') is the largest part of the warehouse which is caused by the issues that are mentioned in section 4.2.1 and will be discussed in chapter 5, but the way that these goods are stored is quite inefficient. Because storage in the central warehouse is assumed to have infinite capacity by the planning department (there are no restrictions to an amount of work planned per period), there are high peaks in input and there are many items in storage that will stay there for an extended period of time. The costs made in the warehouse because goods are much too early are not billed to the department responsible for this. This causes the idea that if goods are too early, there is no problem, or as seems to be the common idea: 'then at least it is on time'. In the central warehouse, there is no difference in the way these goods are stored. They are very easily accessible for all sizes of forklift-trucks within Damen Shipyards Gorinchem, and when it's too heavy it is placed on ground level. This causes quite inefficient use of space here. Also, this causes the average distance to travel to get the items that will be shipped to be larger, adding to the throughput time and this will even lead to errors and misplacements when the warehouse is too full. This leads to the following subquestion:

'How much more efficient can the storage space be used by changes inside the central warehouse and how can this be accomplished?'

This will be discussed in chapter 7: Efficient storage on page 47.

4.2.4. Create shipment

The outbound process, summarized as 'create shipment', uses its space inefficiently. This use of space is visualized with the thick green arrows in figure 4.3. The goods that are taken from storage are collected on the floor into a staging area (the first intermediate storage) the size of a twenty-foot container and are subsequently (in case of large shipments) put into another area where the picked goods are placed (the second intermediate storage). The reservation of space goes per entire twenty-foot container while the release only goes per goods size. Because of this, a lot of space is not usable for other purposes for an extended period of time. These processes before and after the intermediate storages are again (just like the inbound process) not fine tuned to each other, causing much waste of floor space. This leads to the following subquestion:

'How much more efficient can the space be used for the outbound process by changes within the central warehouse and how can this be accomplished?'

This will be discussed in chapter 8: Creating Shipments on page 57.

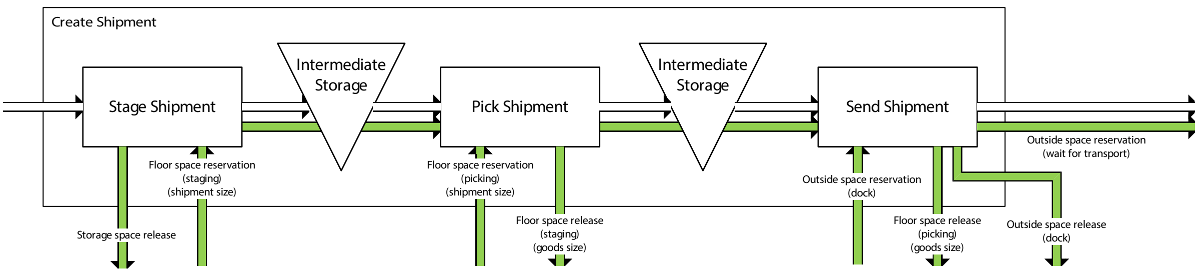


Figure 4.3: A visualization of functions that are not fine tuned to each other

4.3. Research methodology

4.3.1. Just in Time

To answer the first subquestion: 'How much more efficient can the space be used if incoming goods are delivered in time and how can this be reached by changes in the organizational structure?'. This subquestion will first be divided into three parts that have their own research methodology. In the section after that, the possible outcomes of the research will be discussed.

4.3.1.1. Research methodology

This question can be divided into three parts. With the findings, a new way of forming orders can be structured to decrease the amount of early deliveries (and even late deliveries), causing a shorter average time in the system per item. This would indicate (with Little's Law (Little, 1961), equation 2.1) that there are less items in the system, thus requiring less space for the same work, implying more efficient use of space.

'How much inefficiency in space usage does the organizational structure cause?'
By answering this question, the potential reduction in needed space can be found. A large step towards this has already been taken because the analysis in previous chapters was quite elaborate. The translation towards actual efficiency in space usage has to be found by finding out how much space is (on average) used by items that are not planned to leave soon after arrival by using data analysis. If this can then be categorized by working out cases found through data analysis and discussing them with responsible parties within Damen, a total idea of the issue can be found and possible solutions can be formed.

'What defines "in time" for incoming goods?'
A discrepancy has been found between the date that goods should arrive in Gorinchem and the date that they should leave. How can the inbound date be improved so that it is based on the actual need? This will be investigated with interviews, supported cases from data analysis.

'What can be changed in the organizational structure?'
The potential for change must be taken into account to come to a good advice for Damen Shipyards. By taking interviews with managing parties, this potential has to be found out.

4.3.2. Handling Incoming Goods with less space

To answer the second subquestion: 'How much more efficient can the space for incoming goods be used by changes in the method of work and how can this be accomplished?'. The subquestion will be divided into four parts that together form the answer.

4.3.2.1. Research methodology

'How much inefficiency in space usage is caused by incoming goods?' The answer to this question is dependent on the amount of incoming goods and their categories. By analyzing the current method of work, the inefficiency can be quantified.

'What changes are possible in the method of work?' By doing field research and by interviewing people that handle the incoming goods, the unchangeable can be separated from the changeable. The potential profit in time and space will be analyzed by using the Delft Systems Approach. To find out the needed amount of workplaces, data analysis will be used.

'How much efficiency in space usage can be won by this?' By using the possible changes that were found in the previous question, the gain in efficiency can be calculated with the help of data analysis.

'What is necessary to accomplish the possible changes?' Again by interviews and field research, the steps to come to this will be investigated.

4.3.3. Efficient storage

To answer the third subquestion: 'How much more efficient can the storage space be used by changes inside the central warehouse and the order flow, and how can this be accomplished?', the methods in section 4.3.3.1 will be used.

4.3.3.1. Research methodology

Because the contents of the previous facility can be revised upon return, new ways of storing slow-moving goods can be used. The possibilities will have to be found by market research and by studying the solutions used in other companies. Looking at ways to store small packages other than making them a single item on a pallet could also make the space usage more efficient. The dedicated areas per shipyard have to be looked at. Literary research could shed some light onto this. The efficiency can be quantified by looking at the amount of items (lines, units of measurement, or kilograms) per square meter. By looking at alternatives to the current situation and expressing a number of different combination of stored goods in this manner, the best way for Damen Shipyards can be found. The combinations for stored goods will be found through data analysis.

4.3.4. Creating Shipments with less space

To answer the fourth subquestion: 'How much more efficient can the space be used for the outbound process by changes within the central warehouse and how can this be accomplished?', the methods in section 4.3.4.1 will be used.

4.3.4.1. Research methodology

The space for the outbound processes is used quite inefficiently. By continually filling buffers and after that emptying them and by taking fixed areas for this, a large amount of space is wasted. To get a flow back into this process, the applicability for the 'two-bin' system will be researched. To sufficiently test this, interviews with the staff will be taken and concepts will be formed. For the outbound activity, only the moment that the goods are picked can be found in the system and the moment that the container actually leaves the central warehouse in Gorinchem, so data analysis will be used as far as possible. For the DTC-activity (Damen Technical Cooperation), a different concept will be formed. This is the most profitable activity, but also the most space-consuming. This combined with the increase in DTC-activites that is expected will become a challenge in a smaller warehouse.

4.4. Method of expressing efficiency

To measure the inefficiency in space usage, first a unit must be thought of. Aminoff *et al.* (2002) did research in this field to examine the present state of Finnish warehouses and to create guidelines for improving warehouses. They used $\frac{\text{incoming item lines}}{\text{receiving area m2}}$, $\frac{\text{outgoing item lines}}{\text{packaging and shipping area m2}}$ and $\frac{\text{total lines}}{\text{aisle m2}}$. In this, they recognized that 'one item line consists of one warehousing item and that the number of products in an item line, the value of an item line and the weight of an item line vary a lot'. Although this was not addressed by them as an issue, the large difference between space usage for long goods, exceptionally large goods or very small goods cannot be ignored in this process. If 5 m^2 is taken up by one item line, this can be efficient use of space if it the item line is that large, but inefficient if it consists of one small parcel. Also Tompkins and Harmelink (2004) used $\frac{\text{square feet per footprint}}{\text{quantity of unit load stored in the footprint}}$, which although written differently, comes down to the same thing.
Other ways to express efficiency in space usage in a more exact way are examined. The exact size per line is unknown, as the packaging used by the supplier can vary and the dimensions are not measured upon arrival. The weight is measured in the process, but since the density and material use per item line also vary, this can not be directly used to estimate the volume. Some items are put into crates, which makes them at least smaller than the size of the crate. By using the weight percentage of that item line, an estimate can be formed for volume, but this can not be used for items that are for example on pallets, loose, or in bundles which makes it less uniformly applicable. One other alternative is using the location that is used in the warehouse to store those goods. Nothing else than long goods will be stored in racks for long goods (seen in figure 4.4b) and only item lines up to a certain size and weight will fit in the normal racks (seen in figure 4.4c).
It should be clear that in the current process, it will not be possible to use exact volumes for the calculation of efficiency in space usage. To get a picture of the efficiency, the categorization used by Aminoff *et al.* (2002) will be used. By using the area per aisle, a categorization is made that distinguishes aisles for long goods, heave goods and other goods. This will not filter out all exceptions, but will work on average. The space usage will be measured per square meter of floor space, for which the locations in the ERP-system are used. Racks have more storage space per square meter of floor space so they are likely to be more efficient.

(a) Floor storage (b) Storage of long goods (c) Storage in racks

Figure 4.4: Types of storage in the central warehouse

4.5. Final research question

The answer to the final research question should summarize the entire research and thus the question should be accurate. The four parts in which the initial question was divided all offer a part of this. On one hand there is the supply, this is a part that the central warehouse cannot control, but can be improved by changes within Damen and has great consequences for the central warehouse; on the other hand there are the changes in method of work and ways to store goods inside the central warehouse that can be improved in order to store the same amount of goods in less space.

'What can Damen change in the order flow to reduce the amount of goods in the central warehouse and how can these goods be handled more efficiently within the central warehouse so that a return to the previous warehousing facility is made possible by July 2015?'

To get to an answer to this, the reasons for the amount of goods in the system is further investigated. It appears from section 3.2 that a large part of this problem does not lie with the supplier, but comes from inside Damen. Early deliveries, late deliveries and delayed shipments all contribute to a larger amount of goods in the central warehouse, which pushes it to the maximum of its capacity. The way these goods are then handled inside the central warehouse is then investigated. This is divided in three parts, the receipt of goods, the storage of goods and the creation of the shipments. These parts will be handled in their own chapter as the processes are not similar and all account for a large amount of space in the central warehouse.

4.6. Conclusions and recommendations

To come to the steps that can be taken by Damen to return to the previous warehousing facility, the options are laid out and combined to come to a number of options for more efficient use of space in chapter 10: Conclusions on page 69. What other research has to be done and what else Damen can improve in the company is discussed in chapter 11: Recommendations on page 73. In this chapter, the decision to go back to the previous warehousing facility will be taken into question.

5
Just in time

To answer the first subquestion: 'How much more efficient can the space be used if incoming goods are delivered in time and how can this be reached by changes in the organizational structure?', this subquestion has been divided into three parts.

5.1. 'How much inefficiency in space usage does the organizational structure cause?'

As will be handled in chapter 7: Efficient storage on page 47, the average efficiency in space usage (when including all pathways in the sum of the areas) is 0,99 lines per square meter. This means that with the current method of storage, 8118 lines will be stored in 8200 m^2 (this is not a maximum). How this could be improved can be read in the aforementioned chapter.
As the calculations in section 2.5.2.1 on page 13 show, Little's formula suggests that there are around 8843 lines in the system between the approval point (the arrival progress coming from the 'check goods' function in figure 3.8 on page 23) and the picking point (the shipment progress coming from the 'pick shipment' function in figure 3.9 on page 24), because 1020 lines come into the system per workday and they remain between these points for an average of 8,67 workdays. According to their own planning, this should never be more than five workdays, so it is apparent that their own planning does not correspond to reality. These five workdays have been introduced as a buffer so that all goods can come in in time for shipment. As can be seen in figure 2.6 on page 10, this does not have the desired effect.
So how much inefficiency is caused by all this? If the five workdays that is planned is held up, the amount of workdays is reduced with 3,67 workdays, implying a decrease of more than 3700 m^2 with the current way the space is used. Sutherland and Bennett (2007) referred to this in more than one of the seven deadly sins of logistics, in which they applied the seven deadly sins in the 'Toyota Production System', which is mainly applied for production operations, to logistics. Their seven deadly sins of logistics are:

1. *Overproduction* Delivering products before they are needed is overproduction. More serious for the entire supply chain is demand information overproduction—what Toyota calls "created demand." Created demand is caused by requesting a quantity greater than needed for end use or requesting it earlier than needed. Created demand typically adds 40% to supply chain volume fluctuation at the part number level.
2. *Delay/Waiting* Any delay between the end of one activity and the start of the next activity. Examples include the time between the arrival of a truck for a pick-up and the loading of the trailer, and the delay between receiving the customer's order information and beginning to work on fulfilling the order.
3. *Transportation/Conveyance* Unnecessary transport that results in added cost. Examples include out-of-route stops, excessive backhaul, and locating fast-moving inventory to the back of the warehouse causing unnecessary material handling distances to be incurred.

4. *Motion* Unnecessary movement of people, such as walking, reaching and stretching. Examples include extra travel or reaching due to poor storage arrangement or poor ergonomic design of packaging work areas.
5. *Inventory* Any logistics activity that results in more inventory being positioned than needed or in a location other than where needed. Examples include early deliveries, receipt of order for a quantity greater than needed, and inventory in the wrong DC.
6. *Space* Use of space that is less than optimal. Examples include less than full/optimal trailer loads, cartons that are not filled to capacity, inefficient use of warehouse space, and even loads in excess of capacity.
7. *Errors* Any activity that causes rework, unnecessary adjustments or returns. Examples include billing errors, inventory discrepancies and adjustments, and damaged/defective/wrong/mislabeled product.

Of these, number 1 applies to the storage in the central warehouse, because the goods are requested earlier than needed in the planning (the buffer), but also in the deviation of this planning shown in figure 2.5 on page 9. Number 2 also applies because there is a large delay between activities (the buffer). Number 5 is also an issue, because as can be summed in figure 3.4, 48,89% of the goods arrive at least one day before they are planned to arrive (which is already often not relevant to the date that it is planned to be shipped). If everything would come in on the start date for the outbound process, the goods would be in storage for a maximum of one workday, implying that only a 1020 lines would be in storage taking up less than a 1000 square meters if nothing would be improved in the way goods are stored, so this would be by far the best way to decrease the amount of space needed in the central warehouse.

If the goods would arrive in time, this would also mean that the input is predictable, which would allow the central warehouse to plan their capacity or even change the input so that the peaks will be handled better for the incoming goods. This could reduce the space efficiency for the incoming goods quite a lot as a lot of the space is 'needed' to put these goods into a buffer before inspection. If goods arrive closer to the date they are actually needed, the amount of goods that stay in storage because the outbound date is postponed would also be reduced. Also the amount of shipments needed per activity will be reduced by this, as this need is caused by the spread in incoming goods.

5.2. 'What defines "in time" for incoming goods?'

A planner might answer that in time is that the goods are in on the date set by them. The material coordinator might answer that goods are in time if they can be shipped in time. The purchaser might answer that in time is that the goods come in before the date that is agreed upon with the supplier. The warehouse manager might answer that in time is that he can finish the shipments 100% so that they disappear from his planning. The yard just wants all the goods to finish the boat. Whatever their exact answers might be, there is not one definition and this results in the huge spread of arrival dates. The reason for this can be found in figure 3.3 and figure 3.6, simplified in figure 5.1.

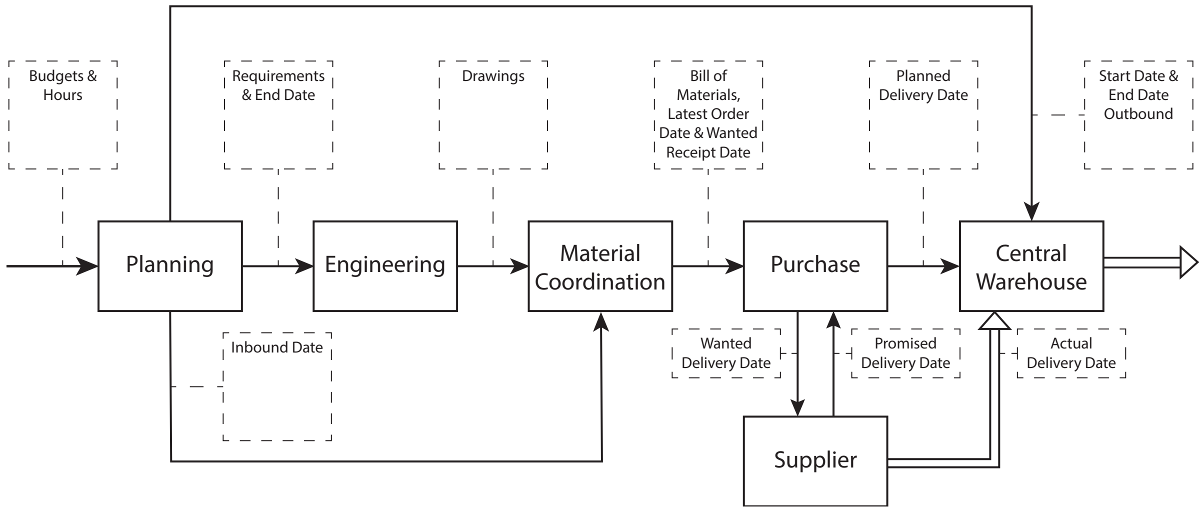


Figure 5.1: Simplified model used to illustrate the parties involved with the arrival of goods

Every department shown in figure 5.1 uses the information that the previous department supplied. The engineering department tries to finish before the end date supplied by the planning department, but has to meet the requirements. The drawings then go to the material coordinators that translate these to purchase requisition orders. The wanted receipt date should be the inbound activity date and the latest order date should be the wanted receipt date minus the estimated lead time that is in the system. The purchase department then does not look at the inbound date, but assumes that the wanted receipt date is the same. They try to order all goods before the latest order date, but sometimes this is in the past or the latest order date is based on old data. They ask the supplier to deliver the goods on the wanted delivery date, which is not always the same as the wanted receipt date, and the supplier can reply that it will be later. The most recent date will be the planned delivery date which should be used by the central warehouse. The supplier can then deviate from its planned delivery date and come to the actual delivery date. If the supplier is much too early, no actions will be taken, but if goods are too late, the supplier will receive a reminder. The result of all this is illustrated with an example in figure 5.2.

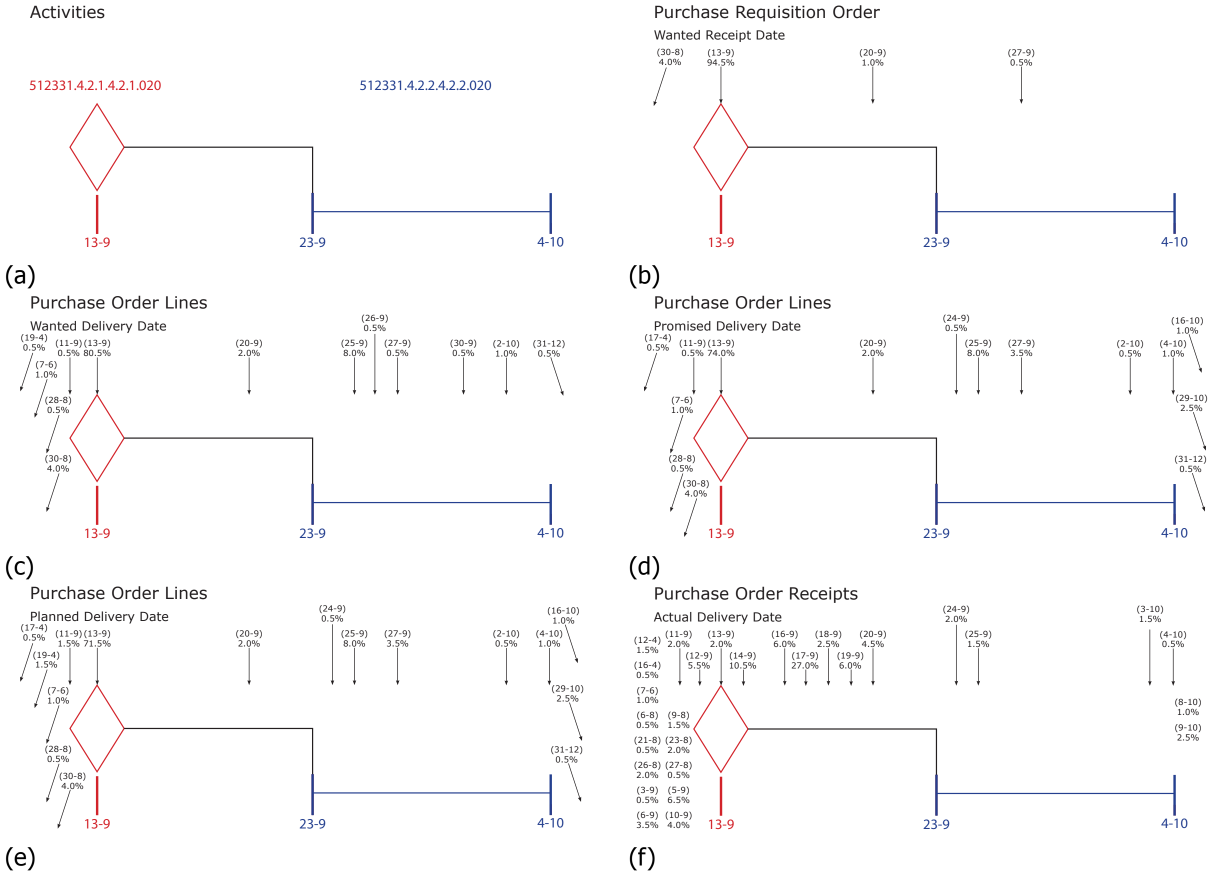


Figure 5.2: Milestones

In figure 5.2a, the inbound activity (September 13th) and the outbound activity (September 23rd until October 4th) are shown for one activity. The planning dictates that these goods should be shipped together. Directly in the second step in figure 5.2b, 5,5% deviates from the inbound date. The wanted delivery date in figure 5.2c differs even more and only 80,5% is the same as the planned inbound date. This goes on through the subsequent steps until in figure 5.2f, only 2,0% of this particular activity comes in on the inbound activity date. This is of course only an example, but this effect has been shown for all lines in chapter 3.
It seems that the freedom every department gets to differ from the date that the previous department provided leads to deviations around deviations in stead of deviations around only the inbound activity date, while the outbound date is still set for the central warehouse. 'In time' should be when it is needed in the outbound process. If the outbound dates change, this should not require human interference to make sure that no orders will be placed on the wrong date. Currently, the inbound date does not change if the outbound date changes. The planning at the headquarters also is not completely fine tuned to the planning at the customer's yard, which could make a rush order in Gorinchem several months early at the customer's yard. Furthermore, goods that need almost no handling are now planned to arrive on the same inbound date as the goods that do require some handling. These goods are often quite large, as this makes repacking unnecessary, and take up a lot of space for almost the entire period without moving. By allowing these goods to be delivered much nearer to the end date of the outbound activity (more 'just in time'), a large space waste is eliminated. The risk that this causes should be analyzed by looking at the suppliers performance.

5.3. 'What can be changed in the organizational structure?'

In the organization, many dates are used as guidelines in the process. Because dates referring to the same moment (the inbound activity date, the wanted receipt date, the planned delivery date and such) have a large spread around the actual needed date, many parts are much too early or too late.

Furthermore, there is no real insight into the costs of warehousing per project.

In figure 3.3 on page 19, the order flow is shown with its flow towards the consolidation function. The date that is used as best estimate of the arrival date was based formed as: inbound activity date - wanted receipt date - wanted delivery date - promised delivery date - planned delivery date. Although there is communication with the supplier in the step from wanted delivery date to promised delivery date, data research has shown that this is still far from the actual delivery date. To avoid constant page-turning, the functions in the order flow that communicate with the consolidation function are displayed in figure 5.3. The supplier results are used solemnly to look at late deliveries, but they are not directly used to confront the suppliers.
The consolidation function would be greatly helped if a more accurate way of predicting the inflow could be found. An option would be to use a more direct method of feed forward by making the suppliers send a signal before delivery. This would result in a direct information arrow from the supplier into the 'receive order' function that will be much more accurate and which is not vulnerable to the influence of unregistered deals that are made with the supplier. *Feedback to supplier*
With clear and insightful feedback from the displayed functions in figure 5.3 to the 'process orders' function, this function could improve in a way that better fits the needs of Damen Shipyards as a whole. Another part in the organizational structure that can be changed is the relation between the planned delivery date and the signal coming into the top of the black tap in figure 5.3 (the start date of the outbound activity) and the relationship between that date and the end date of the outbound activity discussed in subsection 5.3.3.

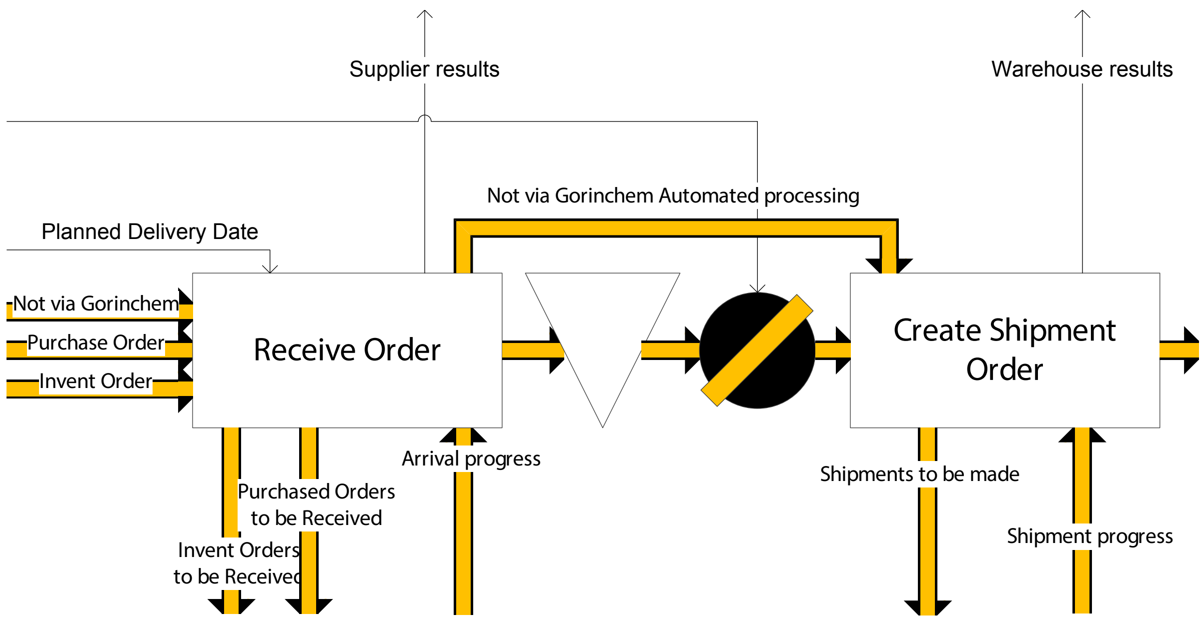


Figure 5.3: Part of the 'handle orders' in figure 3.3 that communicates with the Consolidation function

The average time in storage of 8,67 workdays that was mentioned earlier in this chapter is measured by looking at the time difference between the moment goods are inspected and the moment they are picked. The goods that will never leave are not taken into account there, as they are not picked. It can be assumed that the average time in the system would then be much higher. The quantity of goods in storage is not reliable in the system, nor is the receipt date that is shown there. Because of this the much more reliable inspection date and pick date have been used. If one would use the quantity in inventory according to the system, it would say that in the entire warehouse, on the 16th of May 2014, 21253 goods were in the system of which 11253 were not reserved. Of those items, 5366 are not reserved, not standard planned items (items that are put in inventory), and are linked to an outbound activity. If an item is not linked to an outbound activity, it does not show up on the planning and will not be shipped. The quantity in inventory, as well as the data in table 5.1 are not reliable due to goods that have left but are not registered as such or the other way around, and because if multiple items with the same part number are put in the same location, they both get the receipt date of the oldest one.

Another issue is that the location is unknown after it is reserved, it will remain in storage according tot he system, but with zero available items. This table thus says two things, there is a problem with the reliability of the data, and there is a problem with goods that remain in storage too long.

Table 5.1: Day in storage according to the data from IFS Applications taken on the 16th of May 2014

Days since receipt	Not reserved	Reserved	Total
0	361	24	385
1	1241	281	1522
2	500	193	693
3..4	621	416	1037
5..10	1034	943	1977
11..30	2132	2581	4713
31..100	2949	3227	6176
101..200	1988	719	2707
201..300	192	885	1077
>300	235	731	966
	11253	10000	21253

5.3.1. Feed forward

Because there is currently no good way to predict on what date (or even what week) goods will arrive, the capacity of the warehouse is never considered. This forms a problem for the central warehouse, since this could lead to peaks that cannot be handled and will thus lead to full area's for incoming goods causing large delays. This could be solved if the date suppliers give is the actual delivery date.

Web supplier labeling

The corporation that provides the software for the handheld terminals (Radley Corporation) offers a web service that allows suppliers to print Damen labels there. All they need is a Windows computer, a browser and a label printer. If the printed date would correspond to the arrival date, a better estimation could be given. This would also decrease the amount of work that has to be done upon arrival because the identification of the goods is much less time consuming. When goods are shipped directly from the supplier to the customer, this web supplier labeling would increase the quality as well for the same reasons.

Registering deliveries

Deliveries could be registered before they are sent by the suppliers. If the package list is included digitally in a certain format, it could be automatically registered if it arrives. This would speed up the check of the packing list and could even replace it. This would avoid long lines of trucks waiting to be unloaded, which has caused difficulties in the previous warehousing facility. Without the package list it would at least improve the capacity planning. It could even alter the input if the warehouse capacity is linked to the date the supplier inserts as a delivery date by automatically claiming that the chosen date is overbooked. This would greatly decrease the amount of space needed for the arrival of goods.

5.3.2. Feedback

The only feedback that is really used is that a reminder has to be sent to the supplier when the delivery is late. This does not change anything in the outcome of subsequent deliveries and is thus not an effective way of feedback. There should be a form of feedback inside the company. This could be discussed in project meetings, in which all Damen parties involved (project management, purchaser, material coordinator, etcetera) discuss the ship that is being built. In this meeting the reasons for the early or late arrivals can become apparent and this could improve future shipments. An extra incentive could be to make the costs insightful. Feedback should also be given to the supplier, so that this part of the process can be streamlined. It is probably not the intention of the supplier to delivery on an unwanted date.

Insight into costs

Because the costs for storage are not billed according to the amount of space they use or the amount of time they are stored (but only billed for the inbound transaction and the outbound transaction), it often seems more economically attractive to receive all goods too early ('at least then we'll have it'), to unpack all goods that are already put into containers but are put on hold (because many shipping containers are rented which costs money), and to try to use goods again that were once purchased for a project but canceled (in some cases more than ten years ago). There seems to be no consequence for situations like this, offering no incentive to change, resulting in the long average time in the system and thus the amount of goods in the system.
Because the size of goods is currently unknown, no exact cost for storage can be given. By using the locations in the warehouse as if it were hotel rooms, the costs could be assigned according to the size of the storage space, the check-in date and the check-out date. At this moment the exact check-out date is not registered, but the date it is reserved could be used or the date it is picked. By using locations for goods after they are reserved, this would be resolved. This would also enable outgoing goods to be tracked and decrease the amount of lost goods. The staging location is already inserted in the handheld terminal when it is staged, but this is not registered. Rumor has it that a 'shipping location' is available in IFS Applications that could be used for this.
If for more reasons than this, the size of the goods is measured at the incoming goods section, the costs for storage could be calculated much more accurate. These costs should be used to show the effect of the work that is done by the departments responsible. It can also offer a better approach when a choice has to be made involving storage.

5.3.3. Planning

The time between the start of the 'receive order function' until the end of the 'create shipment order' function is planned in advance. One thing that is not handled here is the amount of work that go into certain parts, or the lack thereof. The most time is needed for small goods, because they have to be consolidated into crates, and large goods can often be shipped as they are received (except for the packing into the container, for which they sometimes need extra attention). Although the large goods need less time to process, they arrive at the same time as the other goods, taking up a lot of space in the central warehouse. This could change and should change in the order flow. Goods that require less processing can arrive much later.

5.4. Conclusion

How much more efficient can the space be used if incoming goods are delivered in time and how can this be reached by changes in the organizational structure?
The entire storage area could be reduced to less than a 1000 m^2 by changes in the organizational structure. To do this, goods should arrive in time and if they are canceled, they should not be stored indefinitely.
In time is now defined at the beginning of the chain, the planning department. The outgoing goods are sent according to the planning, but the goods come in according to a number of translations of that planning. This causes a situation for the central warehouse where they need a lot of space for storage. This also causes large peaks in incoming goods that have to be buffered before inspection which needs a lot of space. The outbound area could be greatly reduced if less shipments would be needed per outbound activity.
By supplying the process with enough feedback, the process can be improved and the outcome can come closer to the desired outcome. This can be done by billing according to storage time and space in stead of only the incoming and outgoing transactions. By demanding more feed forward from the suppliers, a better forecast of the amount of goods that come in can be made. This could go as far as letting the supplier label the goods with Damen labels, which will increase the quality. If peaks can be avoided by acting on that feed forward, the amount of space needed for incoming goods can be decreased.
If the goods would come in when planned, or even better, when needed, both the time in storage and the outbound process time can be reduced.

6
Handling Incoming Goods

To answer the second subquestion: 'How much more efficient can the space for incoming goods be used by changes in the method of work and how can this be accomplished?'. The subquestion will be divided into four parts that together form the answer.

6.1. 'How much inefficiency in space usage is caused by incoming goods?'

Incoming goods has been said in this report to have 4200 m^2 to use. in figure 6.1 the area has been divided into categories with colors. The gray area is storage area and will be discussed in chapter 7.
Facility storage is partially used for goods that are useful for the process like packaging materials and pallets. Another part (the top part) is used mainly to store archives. The reason this building is used for that is simply because they can. This has to be taken into consideration when returning to the previous warehousing facility (there won't be space for this).
Receiving goods is described earlier and consists of fifteen checking lanes and fourteen workstations
Erroneous goods are goods that lack information, are damaged, or will be returned to the supplier. All goods that cannot be processed further will be placed here.
Interaction area is the area in which the delivery truck drivers come in (with or without truck). There is also space reserved for goods that came from the old warehouse or will have to go there. There is a truck that drives back and forth four times a day.
Parking space is the space reserved for the fork lift trucks. They can charge here as well.

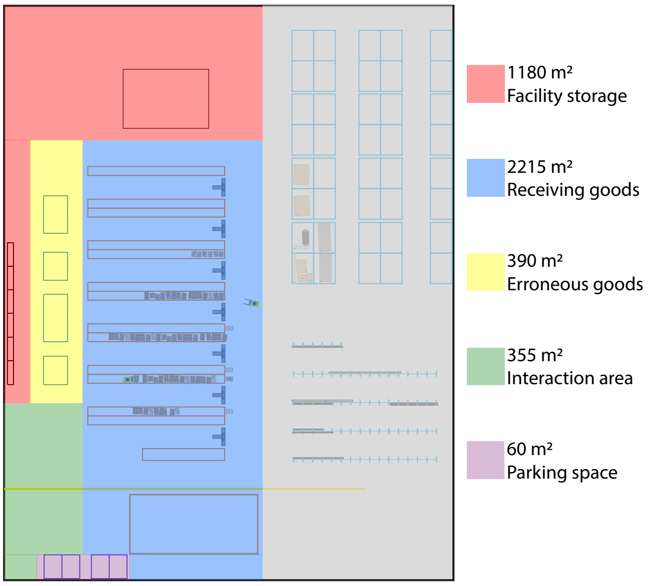


Figure 6.1: Receiving goods section of central warehouse 'Oost'

So how efficient is the space usage? For this, the terms used by Aminoff *et al.* (2002) are used. They mention the number of incoming item lines per square meter of receiving area as a measure for efficiency here. So what can be defined as receiving area? For a return, a part of the interaction area can be reduced, as no transport between warehouses will take place, so only a part will be counted as 'receiving area' (200 m^2). A part of the facility storage is used for materials that are used for this function, so that counts as 'receiving area' (200 m^2).

Since there are either no goods or unregistered goods in locations outside of the area marked as 'receiving goods' in figure 6.1, these cannot be measured by simply looking at the number of lines

in them. For a return to the old warehouse, it is assumed that the need for space for parking and erroneous goods stay the same, and that the interaction area can be limited to the space needed to unload a truck that can be parked inside.
The amount of space needed for facility storage can be limited to only three racks. In this it is assumed that all the goods that are now stored there are valuable for the process. All archived materials and other goods that make up the rest of the facility storage should be stored elsewhere since they do not require frequent access and take up a lot of space.

Concluding this, of the 4200 m^2 available now, only 3065 is actually used for receiving goods and without changing anything the same could be done in even less. Assuming only 3065 m^2 is used, 1020 lines per workday are processed, so the efficiency could be noted as $\frac{1020}{3065} \frac{\text{lines}}{m^2 \cdot \text{workday}}$, how this can be increased will be looked at in the next sections.

6.2. 'What changes are possible in the method of work?'

Intermediate storage is needed because there is a difference between the rate at which the goods arrive and the rate at which they are processed. Figure 6.2 illustrates this for the number of order lines and figure 6.3 illustrates this for the number of orders. The red lines are the difference between the number of arrived items that day and the number of checked items. When there are more arriving items than there are approved (checked) items, the days after that, there are more goods processed than arrived, indicating that the intermediate storages were filled in the mean time. This also results in higher throughput times.

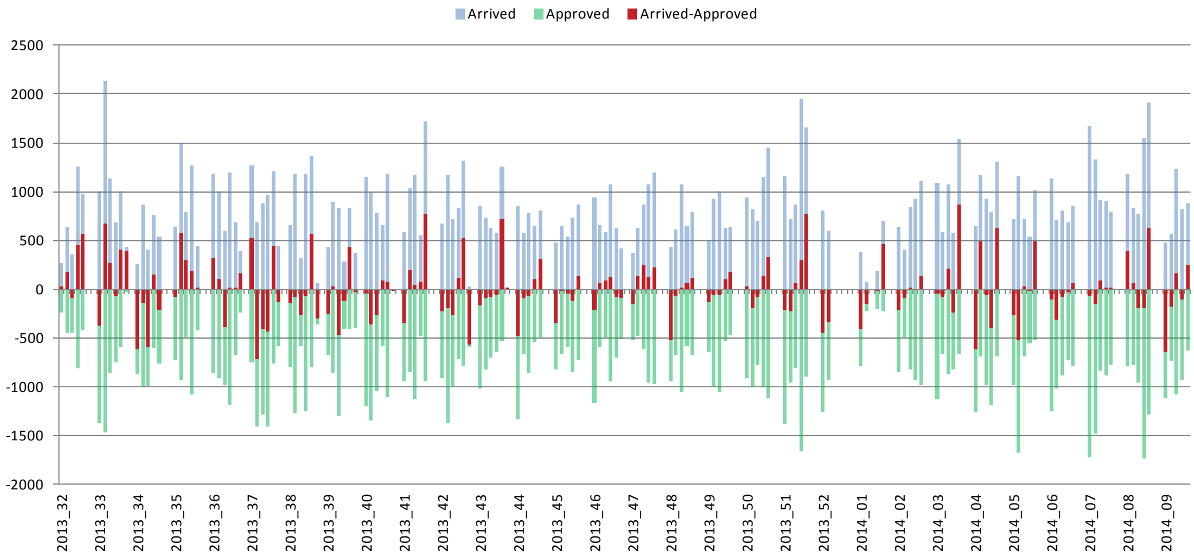


Figure 6.2: Number of order line arrivals and the number of order line approvals per day and their difference

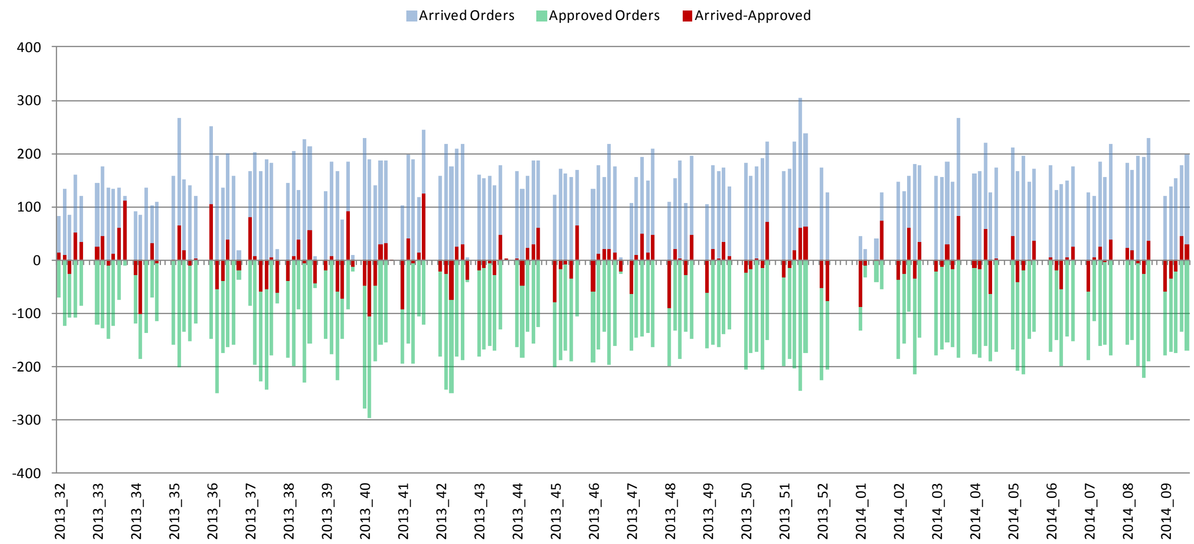


Figure 6.3: Number of order arrivals and the number of order approvals per day and their difference

The system should be able to handle the maximum input without making errors. There are a few ways to decrease the amount of space this takes. One is decreasing the maximum amount of incoming goods, which has to be achieved by improving the planning and actively reacting to it. When more items come in than can be handled by the planned amount of staff, the suppliers could be asked to deliver a day later. Another is decreasing the time needed per order or order line, which could be done by reducing the amount of actions it takes to register and check goods. It is also possible to scrap space that is not used for the receipt of goods as much as possible. In figure 6.1, this is the upper part of the facility storage, where archives are stored, but also the space between the checking lanes in the blue is not used for the receipt of goods.

The amount of workspaces now is fourteen, which takes up a certain amount of space, regardless of the amount of goods that come in. For the period between september 2 and september 13, the checked goods have been watched and there was no moment where there were more than eight unique user ID's used in the checks in ten minutes (see figure 6.4). Although the busiest period might differ from this test sample, it gives the impression that fourteen checking lanes is much more than actually necessary. Every worker has its preferred checking lane and this could cause goods in some checking lanes to have a longer throughput time, especially when the front few items take a lot of time to handle.

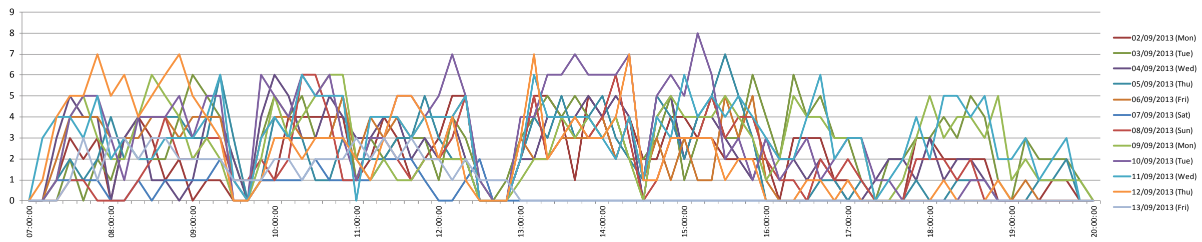


Figure 6.4: Number of unique approver ID's per ten minutes in the central warehouse

Without using the lanes, another way of work could be tried. One conveyor system fit for use with heavy palletized goods and around it a number of workplaces. Goods can be placed on it upon arrival and goods that are checked can be taken off it and put next to their own workspace. In this way the throughput time is minimized and everyone uses the same buffer so no capacity is lost in categories and divisions. The shorter the throughput time, the smaller the amount of space that is necessary for this. Long goods could even slide directly towards a carousel if they are put into cassettes upon arrival. A version of the method of work displayed in figure 6.5, where the goods are placed in only one checking lane on a roller conveyor, could be piloted by pushing the pallets with the fork lift truck to simulate rolling forwards. The existing workplaces could then all pick the goods from one buffer. The different categories could be indicated with different color paper for the arrival sheet, but the way they are processed is the same so everyone there should be able to do it. This would also eliminate the space wasted between the checking lanes.

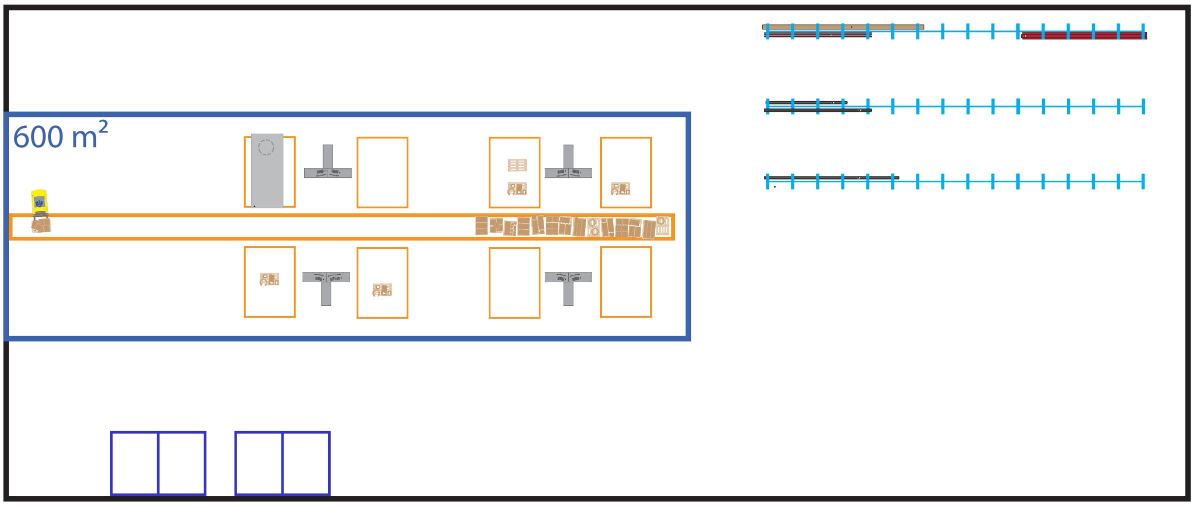


Figure 6.5: Alternative method of work for receiving goods

This concept is not worked out further, but could be piloted like this by the central warehouse. The length of the conveyor system has to be determined and analyzing the number of actions that are necessary to process goods could reduce the amount of actions. This is already looked at within Damen and could bring down the throughput time even more. A system such as displayed is also suitable for large goods, they can be transported directly to one of the workplaces, or even to storage where it can be processed further with handheld terminals. This would again reduce the amount of space needed for incoming goods. Rush orders can also be driven directly to the workplaces so that they are handled sooner.

6.3. 'How much efficiency in space usage can be won by this?'

Assuming that a way can be found to use eight workplaces (or less) with an option to use handheld terminals (which is technically already possible without any changes in the software or hardware) to administer the checking results, it is possible to reserve approximately 1200 m^2 in stead of 2215 m^2 for this function. This would change nothing in the method of work, but the amount of categories that are now used makes reducing the number of workstations difficult. The categories are: two locations for large goods (with one workstation to handle both), one workstation for goods destined for the yard in Gorinchem, seven workstations for 'export', one workstation for diverse goods, one for rush shipments (called 'NAL-LPC / NAL'), one for small parcels and two for the service department.
If 1020 order lines per day are processed, and this would be distributed equally, this would mean almost 73 order lines per day per workplace. It is not probable that the distribution of categories in the arrivals is exactly that, which means that some lanes will be full while others have nothing to do. This is a waste of capacity. If more rush shipments come in than can be handled by that lane, they will be delayed, beating its purpose. An alternative could be to place goods for rush shipments at the front of the row, ensuring that it is handled in time. The way that the goods are handled now, the situation in figure 6.6 could occur.

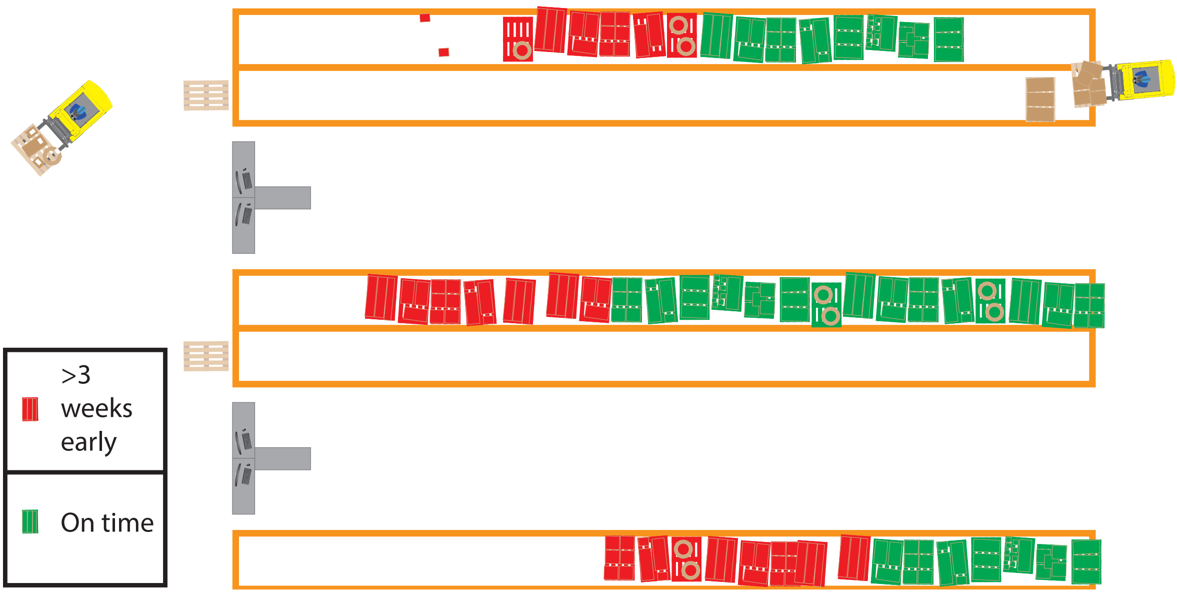


Figure 6.6: Possible consequence of method of work

In this figure, the effect of FIFO (First In First Out) is shown. This is done so that goods are all checked soon after they arrive (within 48 hours), but the result is that goods that shouldn't arrive for at least another few weeks get priority over other goods. Another effect of the way that the goods are handled now is that the front of the lane will be empty until a fork lift truck pushes all pallets forward since there is no form of a belt conveyor. This results in inefficient use of space. Another effect that can be explained with the figure is that there are cases where the red pallets require more processing time, slowing down all goods behind it. This could be solved if the pallets are divided over the lanes according to the amount of work that is in the lanes in stead of on how full it is or what category it is. Using only one checking lane (with a roller conveyor) with the workplaces around it gives many advantages as stated earlier. The concept shown in figure 6.5 is not fully worked out, but it can be assumed that a similar way of receiving goods could reduce the needed space significantly. The total could then be fitted in less than a 1200 m^2 if erroneous goods are handled quickly and thus do not need 390 m^2, if the facility storage is reduced to only what is necessary for the receipt of goods, and if the interaction area is reduced to near none because there is only one warehouse.
Peaks can be handled by adding manpower with handheld terminals. This is already technically possible with the current equipment. Large goods should not be placed in the incoming goods section, but rather placed in storage directly.

6.4. Conclusion

How much more efficient can the space for incoming goods be used by changes in the method of work and how can this be accomplished?
The categorization gives a lot of effects that make for inefficient use of space. By decreasing unused space between the workstations and in the front of the workstations, and by decreasing the number of workstations, this function could be done within 1200 m^2.
To be able to keep processing the goods without errors, the peaks should be processable as well. This can be done by decreasing the peaks or by predicting peaks and acting on it, as has been described in chapter 5. If this is not done, a large area will have to be reserved for the buffer of unchecked goods.

7
Efficient storage

'How much more efficient can the storage space be used by changes inside the central warehouse and the order flow, and how can this be accomplished?'

By taking the rightmost part of figure 3.8 on page 23 and the leftmost part of figure 3.9 on page 24 and combining this with the storage from figure 3.7, a subsystem is formed (shown in figure 7.1). In this subsystem, the question can be translated to finding ways to decrease the flow of space (the green arrows) for the flow of goods (the white arrows) on one hand, and by analyzing what a change in average throughput time in these steps would do for the needed amount of space on the other hand. Because the throughput time of the inventory items is not measurable at this time, the ways to store these more efficiently will not focus on this.

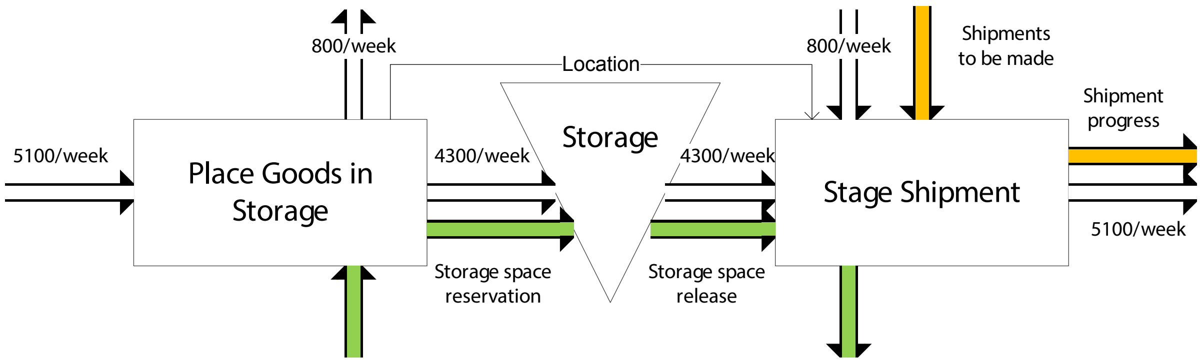


Figure 7.1: Subsystem for storage

7.1. Categorization

According to Tompkins and Harmelink (2004, chapter 13):

> There are two major storage philosophies: fixed location storage and random location storage. In fixed location storage, each SKU[1] is always stored in a specific location, and no other SKU may occupy that location even though the location may be empty. Random location storage allows any SKU to be assigned to any available location. Thus, in a random location storage system, one could find SKU number 1 stored in location A this week and in location B next week.

They state that even though the fixed location storage is by far the easiest storage philosophy, it is very space-consuming. According to them, fixed location storage will generally require 65 percent to 85 percent more space than random location storage. Damen Shipyards uses a combination of these two. The goods are stored randomly within dedicated areas for the country the customer's shipyard is in. A recognizable issue that Tompkins and Harmelink (2004, chapter 13) mentioned is that:

[1] SKU stands for Stock Keeping Unit

> when a SKU is received and placed in the first available location, no matter its velocity, slower-moving items eventually will tend to occupy all the storage locations closest to the dock. Fast-moving items will migrate away from the dock, and increase in travel distance will occur.

The categorization that is used causes honeycombing (unused empty space) of which a good example can be seen in figure 2.14 on page 15. In the location shown in this figure, only goods for a certain project can be placed. Early deliveries will therefore occupy a rather large zone while the actual need for space is limited. On the pallet shown in that figure, honeycombing occurs on a smaller scale. The pallet can only be used for goods that are meant for the same shipment and other items will only get onto that pallet when they are not palletized themselves. Another example of honeycombing is shown in figure 7.2a. These locations are reserved for specific customer's shipyards and can thus not be used for other goods. In figure 7.2b another example of inefficient use of floor space with pallets is shown.

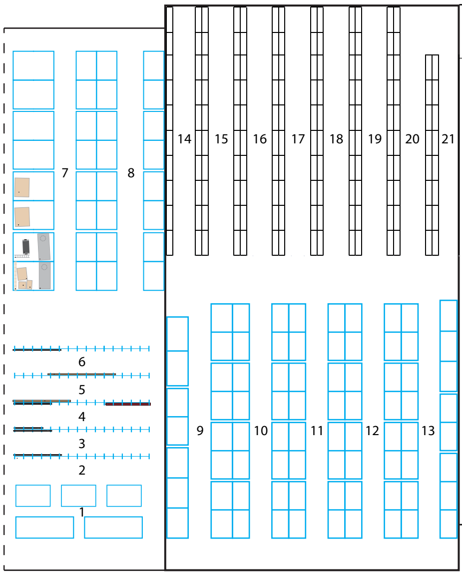
(a)

(b)

Figure 7.2: Honeycombing losses due to categorization in the central warehouse

7.2. Space efficiency

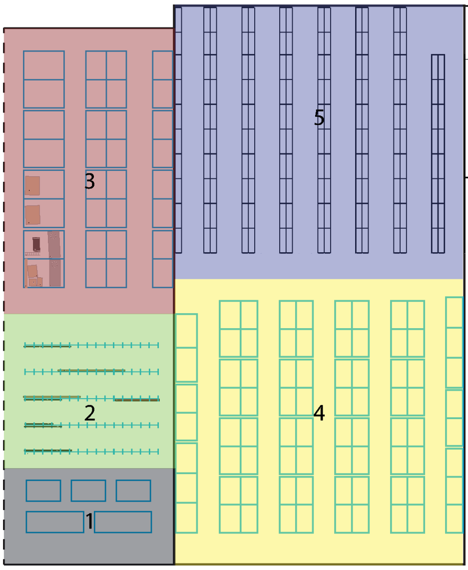
So how much more efficient can the space be used? And how can this be accomplished? Firstly, the number of lines per square meter is calculated:



Aisle	Area (m^2)	2013-10-24 Lines/m^2	2013-12-02 Lines/m^2	2014-02-14 Lines/m^2	2014-03-05 Lines/m^2	Average
1	270	0,05	0,00	0,34	0,67	0,27
2	57	1,16	0,60	1,54	0,49	0,95
3	114	0,11	0,30	0,70	0,46	0,39
4	114	0,46	0,12	0,32	0,41	0,33
5	114	0,25	0,57	1,04	1,25	0,78
6	57	0,88	0,70	0,26	0,77	0,65
7	660	0,11	0,70	1,01	1,39	0,80
8	480	0,73	1,41	0,73	2,46	1,33
9	410	1,67	1,89	2,73	1,66	1,99
10	410	0,79	0,27	1,01	0,37	0,61
11	410	0,18	0,10	0,48	0,60	0,34
12	410	0,91	0,85	1,11	0,45	0,83
13	410	0,05	0,49	1,13	0,84	0,63
14	290	6,51	3,10	4,03	2,78	4,10
15	290	4,80	5,31	2,97	3,98	4,26
16	290	0,66	0,41	1,49	2,15	1,18
17	290	1,03	1,66	1,90	1,61	1,55
18	290	0,28	0,40	1,70	1,42	0,95
19	290	2,95	2,37	3,74	2,67	2,93
20	290	0,73	0,49	1,52	1,23	0,99
21	190	0,28	0,52	1,38	1,22	0,85
Sum	6136					
Average		1,17	1,05	1,48	1,38	1,27

Figure 7.3: Aisle numbering, size and efficiency

In figure 7.3, only the areas that can directly be connected to an aisles have been considered. As can be seen only 6136 of the 8200 m^2 is directly connected to aisles. The remaining area consists mostly of pathways for the forklift trucks. In figure 7.4, the total area has been cut down into categories and the remaining area has been divided over them.



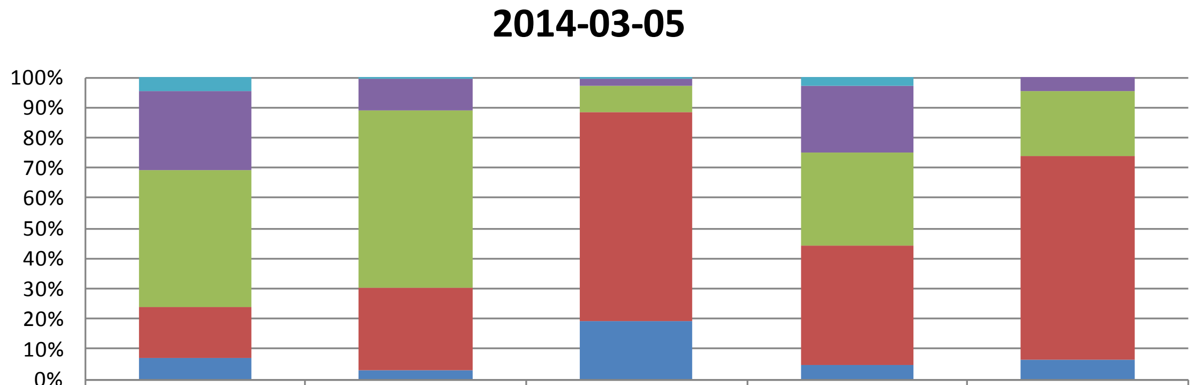
Category	Area (m^2)	2013-10-24 Lines/m^2	2013-12-02 Lines/m^2	2014-02-14 Lines/m^2	2014-03-05 Lines/m^2	Average
1	530	0,03	0,00	0,17	0,34	0,14
2	870	0,24	0,21	0,39	0,36	0,30
3	1600	0,26	0,71	0,64	1,31	0,73
4	2600	0,57	0,57	1,02	0,62	0,69
5	2600	1,91	1,57	2,04	1,86	1,84
Sum	8200					
Average		0,86	0,84	1,14	1,10	0,99

1 Very large goods
2 Long goods
3 Services (floor storage)
4 Heavy and large goods (floor storage)
5 Normal sized goods (racks)

Figure 7.4: Area category numbering, size and efficiency

The average lines per square meter per case has been calculated by dividing the total number of lines by the available space. With less than one line per square meter, it can be assumed that the efficiency in space usage can be improved substantially.
The weight distribution over these categories shown in figure 7.5 does say that heavy items are often placed in area category 1 and 4, but also many items that are much lighter are placed there. Relatively light items placed in area category 1, 3 or 4 are not as efficient as possible because the height of the

warehouse is not used. In the figure, 0 means that no weight is given in the system for that item, 5 means more than 0 kilogram but less than 5 kilograms, 50 means more than 5 kilogram, but less than 50 and so on. Order lines until 50 kilogram should certainly be stored in the racks.



	1	2	3	4	5
>500	8	2	16	51	9
500	48	33	49	347	205
50	82	184	175	500	1059
5	31	86	1454	635	3228
0	13	9	401	75	323

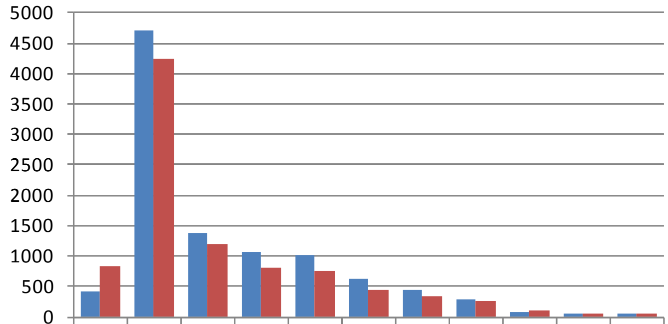
Figure 7.5: Weight (kg) distribution per category

If all items in area category 3 and 4 up to 50 kilograms would be placed in area category 5 (ignoring the 0 kg goods), there would be 2764 lines that can be moved from the inefficient floor storage to the racks. This would increase the efficiency in area category 5 on 5 March 2014 from 1,86 to 2,92 lines per m^2. In addition to this, heavy goods can be placed on the floor under the racks so that the storage area above these goods is still used. This does not count for all heavy goods, but the amount of space reserved for these large goods can certainly be downsized. This can be done without any required investments. As can be seen in figure 7.2b, the floor level is now often used for small parcels. This is done because goods that come in for that same project can then be placed on that same pallet with great ease. This would become more difficult if the floor level storage would be filled with goods that are now put in area category 4 (floor level storage). This leads to the idea that relatively small parcels should not be handled in this way, as they use up much more floor space by using pallets. Although the service department is not an example when taking into account the relevant space usage, as there is much unclarity into when goods should leave, they do store their goods much more efficient when it comes to small parcels. In figure 7.6, taken on 14 February 2014, the racks used for service goods is shown. This is half of aisle 14 (145 m^2) with 855 lines, making the efficiency 5,90 lines/m^2, which makes it much more efficient in space usage than all other storage within the central warehouse. An issue here is that the locations are quite full so finding the right item can take a while. This is because the location does not give the exact location, only which part of the shelf it is. So how could small parcels be stored more efficiently?

Figure 7.6: Service storage

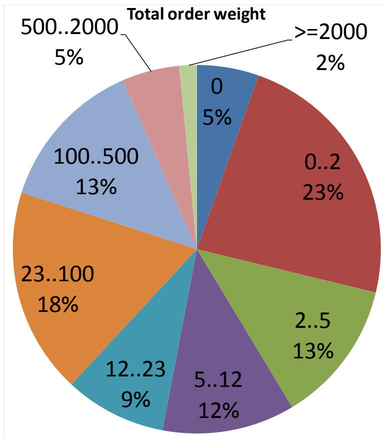
7.2.1. Small parcel handling

There are numerous ways to store small parcels. Although there could be multiple order lines in one parcel, an assumption is made that lines that weigh less than two kilograms are in a small parcel that is light enough to be picked by hand. Of all goods in the areas displayed in figure 7.4, 4247 (47%) of the order lines fall in the category 0 to 2 kilograms (figure 7.7a). On 14 February 2014, this was also 47%. The categorized weight in this figure is the part weight, taken from the system multiplied by the number of parts in the order line. There could be a large space saving opportunity in storing these small parcels in a more efficient way. A better estimation of how many parcels can be lifted by hand is found by using the total order weight as can be seen in figure 7.7b. The truth will be between these two because orders can consist of many parcels and many order lines can be in a parcel, but it can be assumed that there is much to gain by improving the space usage per parcel.



	0	0..2	2..5	5..10	10..25	25..50	50..100	100..250	250..500	500..1000	>1000
14 February 2014	409	4718	1386	1055	1027	633	436	294	90	52	45
5 March 2014	821	4247	1187	796	752	452	334	256	92	41	45

(a) Weight per order line



(b) Weight per order

Figure 7.7: Two methods of estimating the amount of parcels that can be lifted by hand

The racks that are now used are dimensioned for use of pallets. Every rack-section is 4.5 meter wide and four stories high, offering 20 pallet places per section. The top level is never used because the fork lift trucks cannot reach it and because it isn't necessary with the amount of space that is available in the central warehouse now. As could be seen in figure 7.2b, the pallets and their places are not always used to their full capacity. The height, width and depth of the pallet places and the width of the aisles are much larger than is necessary for small goods. Figure 7.8 roughly shows the dimensions of the racks with the pallet places. When imagining a small parcel on these pallets (as is illustrated in figure 7.9), this is obviously inefficient use of space.

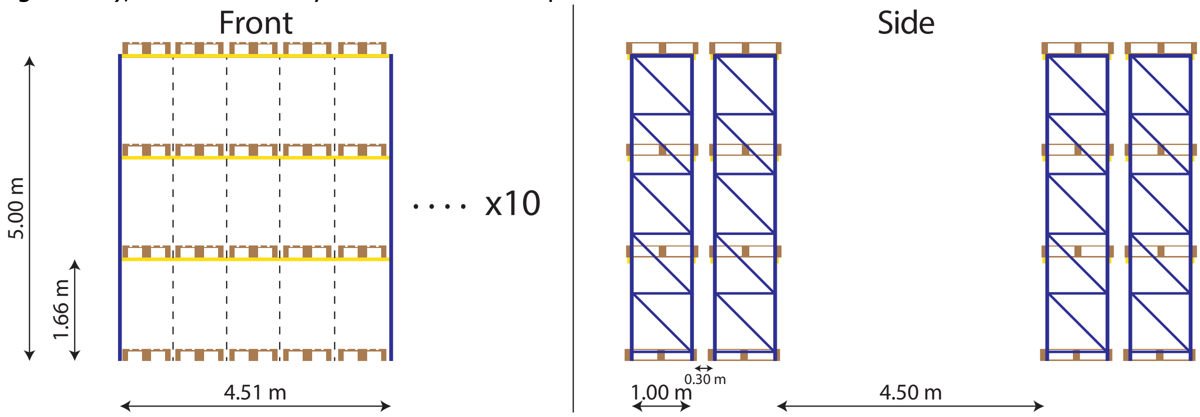


Figure 7.8: Space usage per pallet place

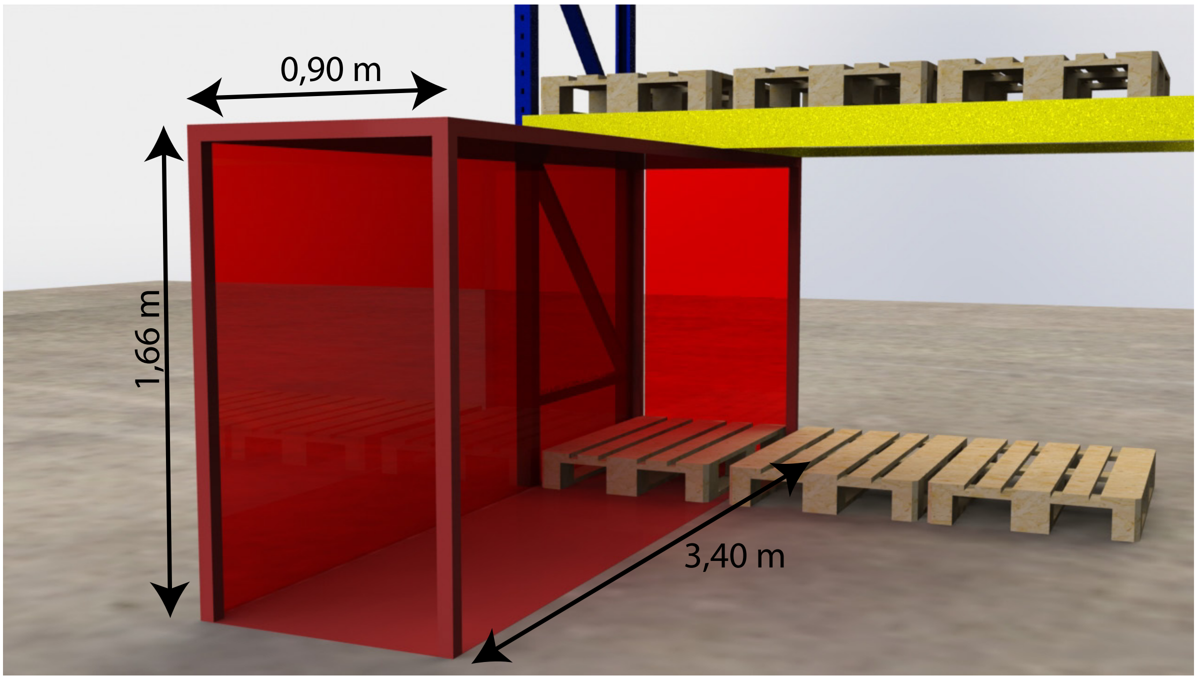


Figure 7.9: Space usage per pallet space

A number of ways to store small goods in less space will be discussed. The advantage of storing goods that can be handled without the use of additional equipment is that the width of the aisles can be reduced. This also has a significant effect on the number of lines per square meter.

7.2.1.1. Quick wins

By using a part of the current racks as is done by the services department (figure 7.6), there is no need to use pallets for these goods. By defining more locations, the goods are found more easily and less honeycombing losses will be present. A disadvantage is that only part of the rack is reachable without the use of special equipment and ideally, the floor level is used for heavier goods to avoid problems with weight limits in the racks.

7.2.1.2. Racks for small goods

By using racks dedicated to small goods, the width of those aisles can be decreased as can be seen in figure 7.10a. The maximum height that parcels can be stored is limited by the reachability.

7.2.1.3. Entresol for small goods

A more space-efficient way of using racks for small goods would be the use of multilevel racks as shown in figure 7.10b. An entresol (second floor) is estimated on 100 euro per square meter by the source of figure 7.10b, which is no scientific article thus can only function as a rough estimate. Because only relatively light parcels would be stored here, there would be no need to strengthen the foundation. To make this safer, an elevator could be used to transport goods between the levels.

7.2.1.4. Movable racks

There is also a way to store goods with a minimum width per aisle by using movable racks (figure 7.10c). This would be best used if someone dedicated to the picking of small packages would do this, as not everyone can pick at the same time. The time needed to pick goods will rise because the shelves have to be moved to enable access. Although random storage is best for space utilization, categorizing by planned outbound date will reduce the amount of moves needed to pick the items.

(a) Narrow-aisle racks
Source: http://www.stow.nl/industriele-stellingen/opslag-van-kleine-goederen

(b) Entresol with racks
Source: www.logistiektotaal.nl/achtergrond/extra-vierkante-meters-voor-weinig-geld

(c) Movable rack
Source: www.southwestsolutions.com/equipment/spacesaver-high-density-storage-shelving

Figure 7.10: Affordable space efficiency enhancers

7.2.1.5. Concept for the storage of small goods

A concept of how the new small goods storage could look is shown in figure 7.11. The width of the aisles could be much lower because there is no need for fork lift trucks. For this example two sizes of parcels are shown, one $0.6m \times 0.6m \times 0.45m$ and one $0.45m \times 0.45m \times 0.3m$. The exact size that is reserved per parcel should be determined by Damen and should suit most goods that can be lifted by hand. With the assumptions made in the figure, one aisle could make room for $20 \times (15 + 28) = 860$ Parcel Places and would have a total width of 2.40 meters (8 parcels per square meter). The current situation offers $20 \times 15 = 300$ Pallet Places and has a total width of 6.50 meters (the few pallet places that are left out to create a passage have been ignored in both situations). This means that even if every pallet would have more than 7 parcels on them, and the parcel places in the concept would be dimensioned for parcels that are really this large and would contain only one parcel per location, the current situation would still be less efficient than the concept. One parcel per location would result in less time lost in searching for goods, as is the case with the service storage shown in figure 7.6. Another disadvantage of this way (used by the service department) to store small goods is that the errors in locations in IFS Applications have been traced back to instances where multiple parcels with the same part number have been stored on the same location and this is often the case here. Goods that are then reserved are sometimes reserved from different parcels, creating wrong locations being shown in IFS for goods that remain.

Even with the wide parcel places in the concept, eight parcels would be placed per square meter, which would make around 500 square meters enough to store all small goods (more than 4000 order lines are in less than 4000 parcels).

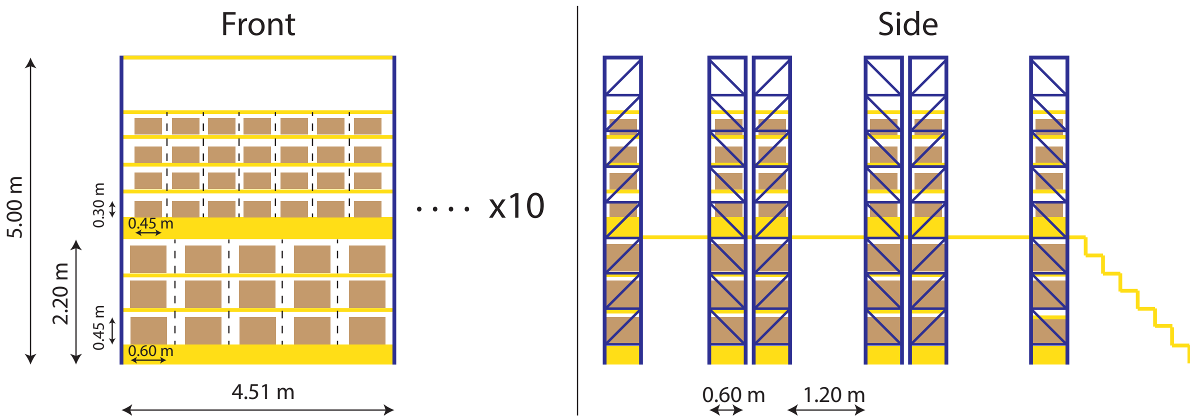


Figure 7.11: Concept for the storage of small goods

7.2.2. Long goods handling

Area category 2 (870 m^2) in figure 7.4 is filled purely with long goods. These have to be handled by a specialized fork lift truck (a side loader) because it needs to be transported sideways. Because this forklift truck has no turning cycle, it can work with much smaller aisles. The racks that are used, however, are not that high. This causes an average efficiency over four measuring days of 0,30 lines per square meter. A way to reduce row width and used height is to install a vertical carousel (figure 7.12).

On average, 21.07 transactions are registered into the long goods storage[2] and 16.81 are registered out of the long goods storage per day. In weights this is 689 kilogram in and 589 kilogram out. The distribution in this can be seen in figure 7.13.

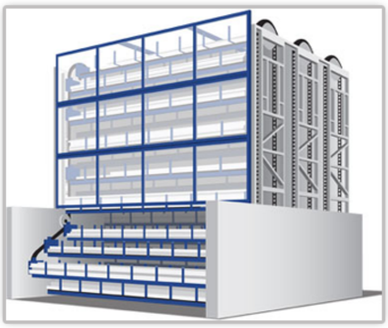
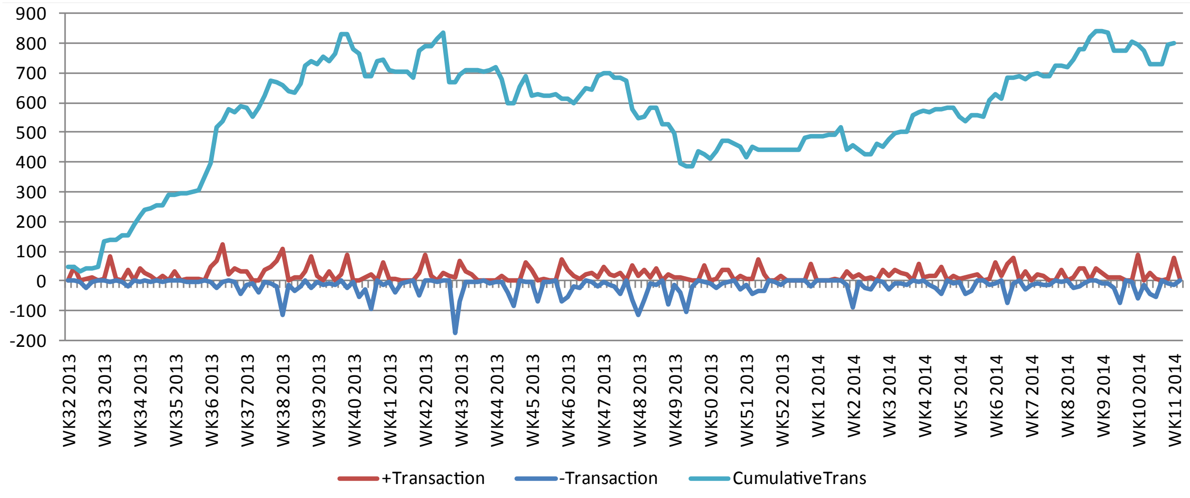
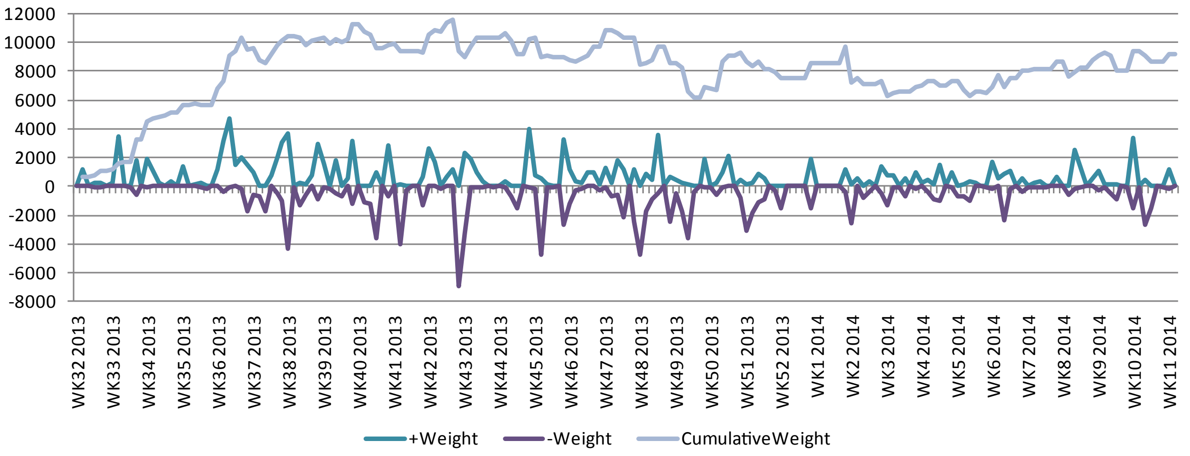


Figure 7.12: Example of a vertical carousel for long goods
Source: http://www.verticalcarousel.com.au/product_details.php?catid=NA==

[2] locations MAF, MAG, MAH and MAI



(a) Number of transactions from and to long goods storage



(b) Weights from and to long goods storage

Figure 7.13: Inputs and outputs for long goods storage

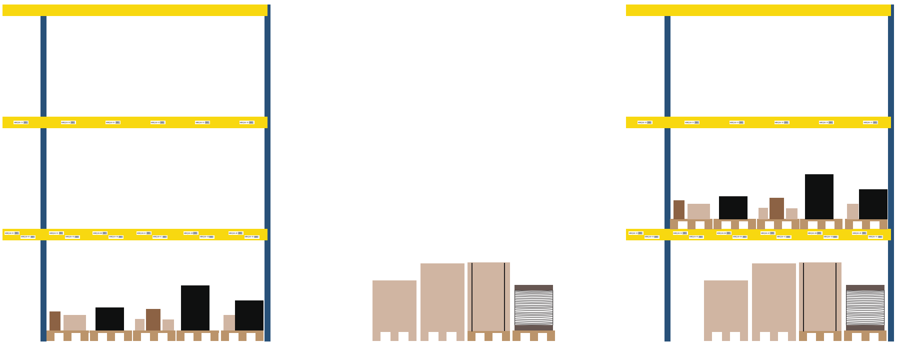
Of all that has left the long goods storage in the period that was watched (from the first transaction into the long goods section until March 12 2014), the average time that it was in one location (according to the system) is 27.8 days and is distributed as is shown in table 7.1. This also fuels the idea that the amount of transactions in and out of this type of storage is not very high so even if (for example) the vertical carousel would be slower than the way it is picked now, it would still be an alternative. The goods that were on one location for less than a day were mainly internal transfers (144/151 were moves to another location in storage).

Table 7.1: Time in system for long goods storage

Days	**>=**	**0**	**1**	**3**	**5**	**8**	**11**	**15**	**22**	**29**	**36**	**61**	**91**
	<=	**0**	**2**	**4**	**7**	**10**	**14**	**21**	**28**	**35**	**60**	**90**	**∞**
	In and out	157	70	126	126	146	166	401	596	522	669	160	36
	In, not out	5	82	0	30	87	26	124	44	93	122	63	90

Another alternative that could be researched would be the stackable cantilever racks for long goods. These can filled and then lifted by a crane to use more height. The time needed to get the items at the bottom could go up a lot so it would be up to Damen to decide if this is worth investigating.

7.2.3. Heavy goods storage



(a) Example of the current situation in the central warehouse

(b) Opportunity for improvement in efficiency in space usage

Figure 7.14: More efficient use of space with racks and floor storage

As was mentioned earlier in this section (7.2), space above the floor storage is not used in area category 3 and 4 (1600 m^2 and 2600 m^2 in figure 7.4). In addition to this, relatively light items are stored here while they could be stored in racks. This space could be used more efficiently if racks would be placed above them, or when these goods would be placed on the floor under the racks. For some items this is not possible because they are too large. For these items, there will still be a need for floor storage. An illustration has been added in figure 7.14. If (nearly) all heavy goods would be placed under the racks and if possible in the racks, the efficiency in space usage would go up. With the emptier racks after separating the smaller goods, this should fit in the space currently available for racks.

7.3. Other efficiency

The efficiency in space usage is largely expressed in number of lines per square meter, but another definition for efficient use of space would be to only store goods that are necessary. This type of efficiency should be enhanced by what is discussed in chapter 5.

7.4. Conclusion

How much more efficient can the storage space be used by changes inside the central warehouse and the order flow, and how can this be accomplished? There are an average of 0,99 order lines per square meter. This is caused by wide aisles, not making use of the height, and dedicated storage. By storing small goods (47% of the order lines) randomly and in smaller aisles, by storing heavy goods under racks to make the space above it usable, and by storing long goods in a new way, the amount of space needed will be much smaller.

8
Creating Shipments

The fourth subquestion: 'How much more efficient can the space be used for the outbound process by changes within the central warehouse and how can this be accomplished?'. This will be handled for different cases. The normal situation when goods are shipped in containers, the case of the rush and small shipments like airfreight and courier shipments, and the DTC case, in which the process is a lot more tedious and space consuming.

8.1. Normal shipments

It has been mentioned in section 3.3.3 that the outbound side does not use their space efficiently. This is explained by making use of the model in figure 8.1 (for orientation, the 'create shipment' function comes after the storage in figure 3.7).

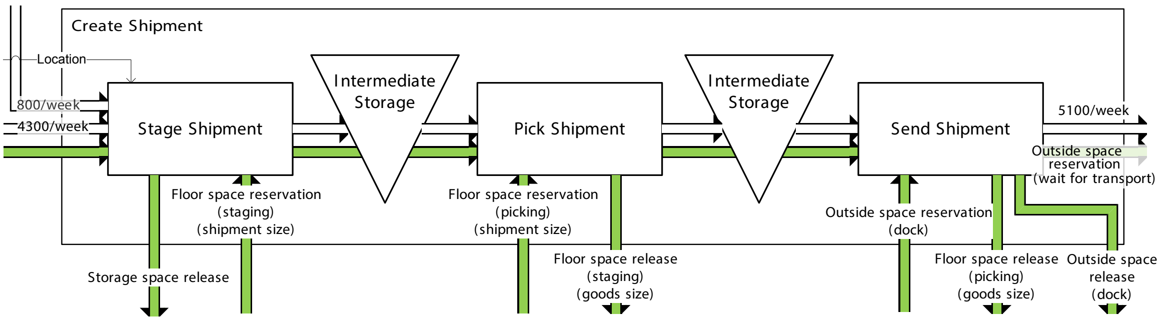


Figure 8.1: The 'create shipment' function with the use of space

When the goods are collected from storage (which is called 'staging' at Damen Shipyards), they will be laid out on the floor. Thus some storage space is released, but an entire area (11 m · 2.5 m = 27.5 m^2) will be reserved for that shipment. This area will gradually be filled up with more goods from storage until either the picklist is depleted or the area is full. Then the goods are placed into handling units (which is called 'picking' at Damen Shipyards). This means that the goods are put into a unit in which they can be shipped. When this process starts, another area of 27.5 m^2 is often reserved, because the previous area has been filled up. This continues until the staging area is empty upon which all remaining goods will be staged. The staging and picking is almost always done by the same person. This is a very time and space consuming method of work. When the area for goods that should go into a container is available, it will be filled with that shipment. In the process of transporting the goods from the picking location to the shipping location, the same effect occurs. Two area's will be reserved for it.

8.1.1. Delays

There are a number of delays in this process. Because every delay causes additional use of space and thus a less efficient process, they are worked out in this section.

8.1.1.1. Digital versus Analog

One of the delays is the digital versus analog processing which is illustrated in figure 8.2 and modeled in figure 8.3.

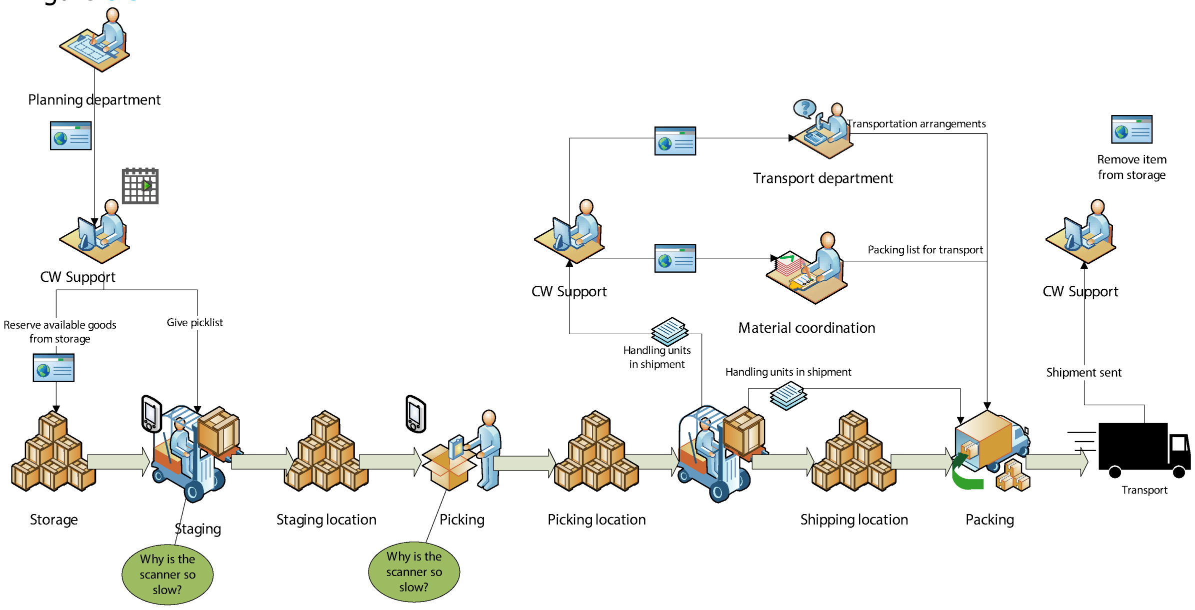


Figure 8.2: Creating shipments 'as is'

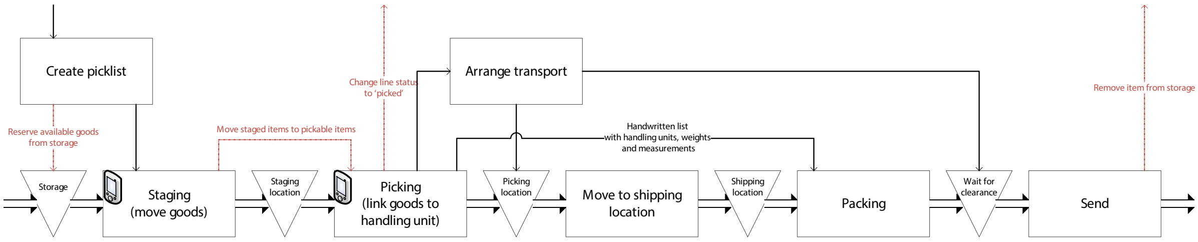


Figure 8.3: Creating shipments 'as is'

8.1.1.2. Digital processing

The hand-held terminals (or 'scanners') that are used to process the goods account for a large part of the delay. This is also depicted as the most important thought and complaint in this process in figure 8.2.

Staging

Incoming goods that are meant for the same activity are put into a 'Movable Unit' or 'MU'. By using this, goods can be moved from one place to another as a group. Staging should also just be just a move from one place to another, and this information is also entered into the hand-held terminals, but nothing in the items location changes. This is because it is thought that the 'picklist' is an offline list and because of that, no goods on the list should be moved. The only function it has is thus making the items pickable for the next function. This can be seen by the absence of a red arrow to the computer system in figure 8.3. The way it was once thought out was that goods would be staged on the moment they are taken from storage, but since the barcode with the location to which it should be staged (which eventually doesn't show up in IFS) is quite far away from that, this step is done after almost all goods are moved. All goods that are suspected to be in that shipment are taken from storage in stead of the ones indicated by the handheld terminal. Goods that they have moved that are not on the shipment are either returned or added to the shipment.
This is of course not the way it was intended. Which is shown in figure 8.4.

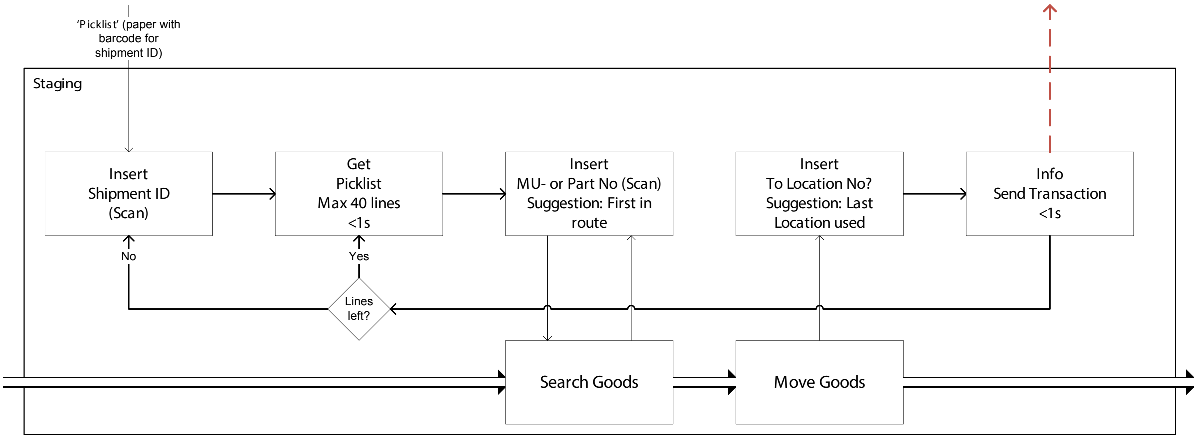


Figure 8.4: Staging as it was intended

The shipment ID is scanned and a list is loaded, sorted on an ideal route. The fork lift truck is driven to the location on the handheld terminal (which always displays the correct location). The MU-barcodes are scanned and the goods are moved from the storage location to the picking location on the moment they are moved. This should be visible in the system so that an accurate status is known for the storage. Immediately when the goods are placed in the 'staging location', they can be picked by the next person.
This is not the case in reality, it is close to it but looks like figure 8.5.

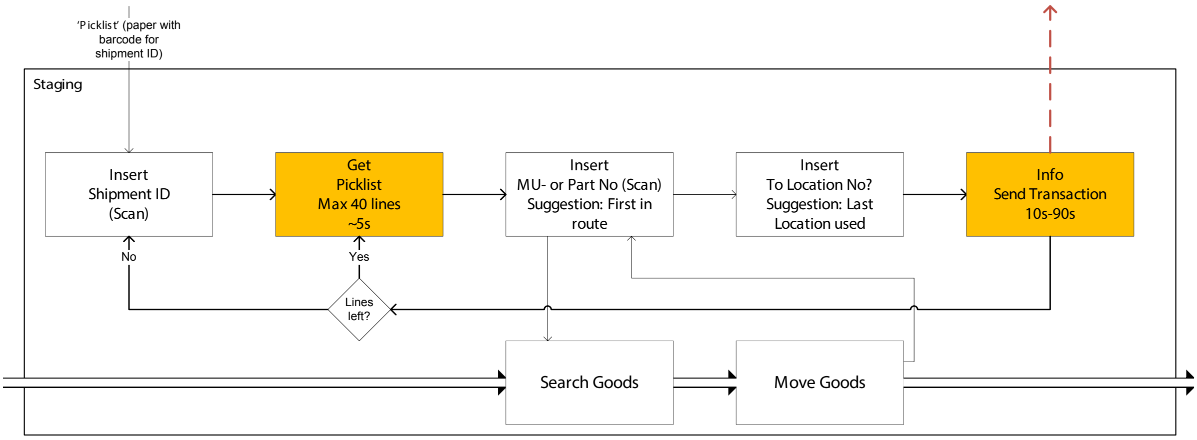


Figure 8.5: Staging as it is

The shipment ID is scanned and a list is loaded, sorted on a route once determined, but not taking into account the size of the goods, causing the route to be inefficient and unused and the location given by the handheld terminals is not always accurate. The fork lift is driven towards a location that seems to be holding a lot of the needed items and pallets from there are moved to the staging location. They are left there until the staging area is full and then they scan the MU-barcodes and link them to the staging location. This is a large waste of time as the 'send transaction step' can take up to 90 seconds if the shipment contains a lot of lines. If this is the case, the query is timed out and they will have to scan the shipment ID all over again. And this all is done to move the lines form the 'staging buffer' to the 'picking buffer', which it could have been in in the first place. They then proceed with the picking themselves.
The entire step is seemingly useless and could be skipped. How many lines there are per Movable Unit is not registered so no exact calculation of loss of time can be done here. The added value of this step according to the people on the work floor is that by doing this, you can collect enough items to efficiently fill a handling unit (often a crate). This of course does not count for items that will not be put into crates. If the goods would have a known size (measured at the incoming goods department), this could be done differently.

Picking

The picking step always comes after the staging step since the digital 'picklist' is filled with goods that are staged. The large difference between this step and the staging step is that you cannot use Movable Units and thus have to handle every single order line.

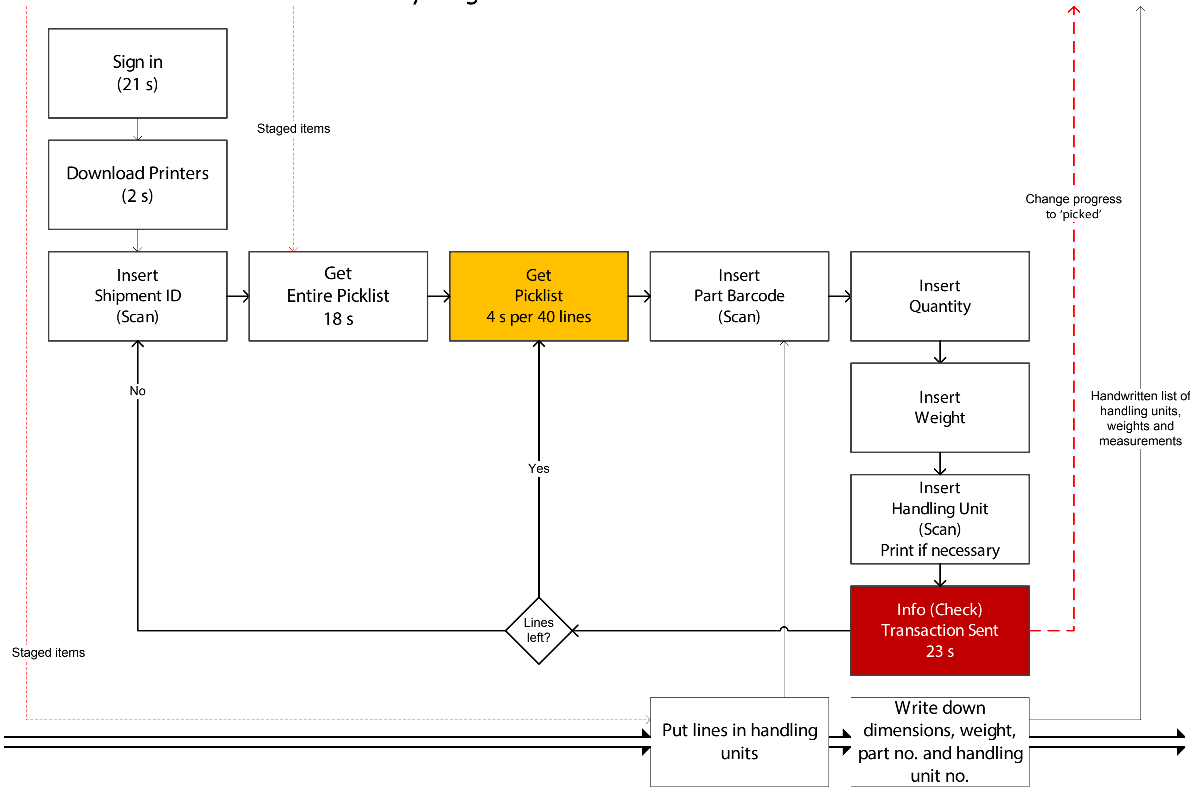


Figure 8.6: Picking as it is

The times in figure 8.6 have been measured for the picking of a shipment of 249 order lines. Other measurements indicate that less order lines means less time and more order lines can make the 'Transaction sent' message be displayed for more than sixty seconds. For this order, it would mean $249 \cdot 4s + 249 \cdot 23s + 1 \cdot 21s + 1 \cdot 2s + 1 \cdot 18s = 1{:}52{:}42\ (6764s)$ is used for only waiting for the handheld terminal to respond. The tempo is severely disrupted and the morale of the people working with it is decreasing a lot. The thing that is perceived as the worst is the picking of certain prepared crates. More than a hundred lines could be in these crates that will not be opened in the warehouse, but they are handled as more than a hundred order lines, causing the processing to be very tedious, as nothing actually changes. This is sometimes done in the cafeteria with two handheld terminals. Another problem is that the handling units have no location. So if a shipment is put on hold for whatever reason, it could be lost if the one that put it away somewhere is not there. This usually goes right because there is so much space to just leave it standing in the picking area until it can be packed.

8.1.2. Space usage

As was said before, the way the process is set up makes it necessary to have staging, picking and/or packing areas. All these areas do not use the height available, but rather spread all goods out on the floor. Although the very inefficient 1 line per square meter that is averaged in storage is probably even improved by stacking it neatly together, the potential maximum for this is much lower. If handling units would be able to have locations, they could be stored much more efficiently and can be picked from there by the packers when ready.

8.1.3. Concept 1

A future situation with much less space usage looks like the process in figure 8.7. If small goods would be stored as suggested in section 7.2.1 on page 51, the absence of the staging step would make it possible to walk past the racks with a crate (handling unit) and put the goods in the handling unit while walking through it. This would eliminate the need for staging and picking areas. Larger goods that have little or no processing times could be handled by sticking the label on it while it is still in storage, again eliminating the need for staging and picking areas. It would be useful if this can be done per Movable Unit, so that this is a simple action for prepared crates. These goods could be delivered just before the shipment is sent because there is so little processing time. This would decrease the needed amount of storage. If the sizes and weights of the handling units are registered digitally, the packing list could be printed automatically without the need for material coordinators. No interpreting has to be done by central warehouse support, eliminating errors. If goods can always have a location, the location to store incoming goods can be handled by a computer program on forehand. Now this is impossible because there is no difference in the location from the moment they are reserved until they are sent and thus 'reserved' items could be in storage or in a shipping container already.

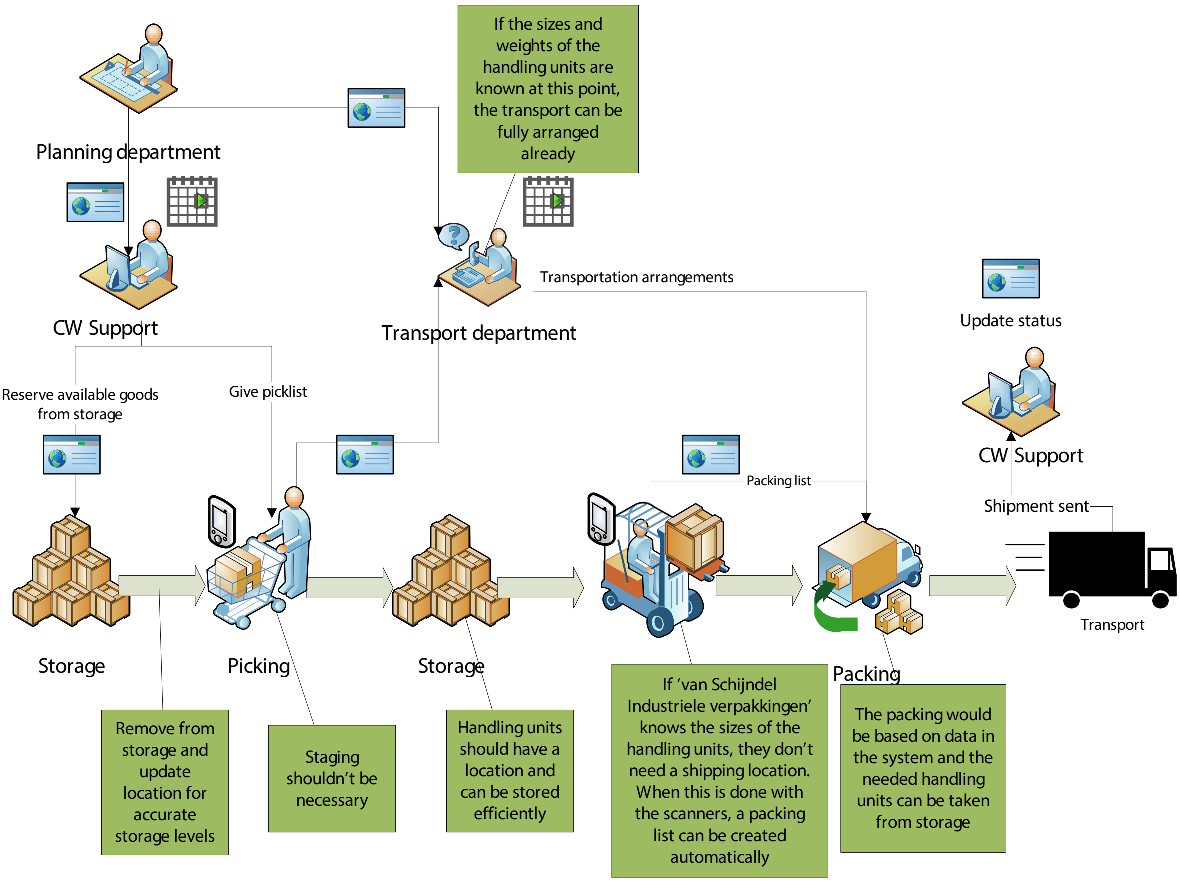


Figure 8.7: Creating shipments 'to be'

So what is needed for this?

8.1.3.1. Requirements

Most changes have to be arranged with Radley Corporation, the supplier of the middleware that lets the scanners communicate with the ERP system (IFS):

`Goods should be weighed and measured upon arrival.`

If the package the goods came in is already suitable as handling unit, this eliminates the need to do this later in the process and thus decreases handling time.

`It should become possible to pick without staging or the whole staging step should be eliminated.`

This would reduce the amount of space needed by a large amount.

`Goods should be movable by the 'owner' of the picklist.`

In this way, it will be exactly in the place the picklist indicates, but when it is moved towards a staging location or elsewhere, it is not digitally lost like it is now. One extra advantage is that the exact amount of storage used is known and that empty locations can be found by looking in the system in stead of walking by it. In the case of a separate small goods storage with more- and random locations, this would be essential.

`Handling units should have a location so they can stay in storage or can be stored together with other handling units for a certain shipment.`

Handling units now have no location, so the goods cannot be moved to a more suitable location after they have been picked. If they would have locations, the goods could be picked for the shipment and put into the shipping container digitally by setting the container number as location, making the packing list creation suitable for automation.

8.1.4. Concept 2

Without changing the middleware, there are still many things to accomplish in space usage by creating a flow through the current system, in stead of the discrete (step by step) way it is handled now. Using the staging area as a means to estimate the size of the shipment does not fit in any more space efficient way of creating shipments. By staging like this, a buffer (the staging area) will always be filled entirely before it is processed further, requiring even more than only the shipping-container-sized area on the floor. By immediately processing goods that have been staged, a flow is created that uses less floor space. By storing these processed or 'picked' items in racks, it will use even less space. To efficiently keep the flow in this process, there should be a signal that makes sure the picking process (seen as a continuous process) does not run out of goods to continue. It should also not receive too much goods, causing the amount of available work space to decrease. Processed goods can be picked up to be stored more efficiently. To enable this process to work without having to fill the entire area to estimate the amount that fits inside a container, the sizes should be known before that. This could be done by the incoming goods section and could even be automated.

If the weights and dimensions are known, the content of the shipping container could be planned on forehand. On a smaller scale, even the picklists can be sorted according to which items fit inside a specific crate so that the process is made even simpler and so that no more goods than necessary for that crate will be transported from storage towards the (small) staging area. This staging area could be used like a two-bin system. An example of this is the system where two bins with bolts are placed behind each other, the front one is used for the bolts that can be used for the process and when it is empty, it will be filled with the bolts in the second bin, setting of a signal for new ones to be ordered. This second bin was filled with enough bolts to be used until the next delivery of bolts comes in from the supplier. Applying this concept to the staging and picking process, goods will be placed inside a buffer area, which will be emptied when the amount of goods to be picked is too small. When this buffer area is empty, it sends a signal to a fork lift truck driver to get the next batch of goods. By doing it like this, the picking process is not interrupted. If for whatever reason an empty staging (or buffer-) area should not be filled, this could be signaled by simply putting an orange cone inside the area. What to pick can be seen from the fork lift truck by driving by the staging areas and scanning the barcode that is put up next to an empty staging area. This all is already possible without changing the computer system. Functionality to be added is to arrange the order of the picklist to what can be used then in the picking process. For this, the weights and dimensions are needed and have to be categorized in such a way that the result offers a good filling for the crates and eventually the shipping container.

To be able to store picked goods (with the handling units) more efficiently, they could be put together in a rack. The location would then be the filter as to what goods belong to what shipment, combined with the handling units that are written down by the picker. Another option is allowing the goods to be randomly stored and putting the location of the handling units into the system. This would give another transporting step to the outbound process, but would allow this to be done with less floor space usage.

When goods need less processing time (when they already arrive in seaworthy packaging), they could arrive later, decreasing the amount of goods in the system. For this, the suppliers performance should be much higher or at least the large amount of data should be used to select which suppliers can be used for this.

8.2. Rush and small shipments

Rush shipments should be formed into a handling unit upon arrival, as they should leave as soon as possible. Small shipments can be stored at random and should be processed in less space than other shipments. Currently the same 11m x 2,5m is reserved for just a tiny shipment.
Goods are now checked and put into storage and subsequently staged, picked and put into a location for pickup by a courier or by an air transport company. When goods are really that much in a hurry that they won't be sent by shipping container, they should be able to go through the process in almost no-time at all. An option for this is to make it possible to immediately repack the goods when they come in and label them with the handling unit labels so that they can be shipped as soon as possible. Wherever these shipments are handled, they require less space than the goods that go in a shipping container and thus should not be processed in an area fit for a shipment the size of a shipping container.

8.3. DTC shipment

DTC shipments take a lot of space because they are (in some cases) laid out on the floor waiting for approval of the customer. It has happened numerous times that the customer was delayed and that the goods had to stay laid out on the floor for weeks. This is partly a communication problem. If there is a delay causing the customer to come in later, this should directly be told to the people handling that shipment and they could even be fined if the space usage would be billed as suggested earlier. Goods in a DTC shipment all have a function code (also called IDK- or system code) which indicates for what part of the ship or process they are required. The goods are all consolidated according to their function code by laying them out on different pallets for different function codes. The pallet list with all the products and their function codes is then put onto a pallet list that the customer uses to check if it is all in order. If the goods would be stored per function number, they can be taken from storage when needed and not earlier. It is even possible to plan which goods will be taken out when for optimal space usage. There would then be a planning as to when the inspection of what goods would take place.

The DTC outbound activity takes four weeks while other outbound activities take only two weeks. This is partly caused by the goods coming in with the same large spread in arrival dates, while shipments should be sent complete in order for the ship to be built correctly at the customers yard. The four weeks is largely used as buffer to be able to receive everything. Another part making the process such a long one is that goods are staged and every item is then picked up, the function code is searched on the label, the function code is then searched on a list with function codes with the handling unit they are in and then the handling unit is searched, the item is placed on the pallet and the administrative step in the handheld terminals is completed. If the handheld terminal would indicate (as a suggested entry in the handling unit field) what handling unit other goods of that function code are in (this could even be inserted in IFS on forehand), this process would be simplified. An item would be scanned, and without looking it up it could be placed in the right handling unit. If the goods would be stored according to the function code, it would be even simpler.

8.4. Conclusion

How much more efficient can the space be used for the outbound process by changes within the central warehouse and how can this be accomplished?
The method of work requires a large amount of space. There is no real flow in the process, one buffer is filled and subsequently emptied into another buffer (staging and picking). By emptying the first buffer while it is being filled, much less space is needed. It is even possible to skip the staging step entirely, but to do this changes have to be made in the software architecture and this takes a long time. If the staging step is skipped, goods that arrive in seaworthy packaging could immediately be processed to become a handling unit after which it will need almost no extra work. Now these goods have to be staged, individually picked and then packed. Furthermore the administrative steps take up a long time, by improving this the time the outbound process needs is reduced.
If goods keep coming in so randomly as discussed in chapter 5, a reduced time needed for the outbound

process would imply that less goods would arrive in time for the shipment. Furthermore the goods that are put 'on hold' at the outbound side can now not be moved to more efficient storage because these goods have no location in the system. They would thus become lost if placed elsewhere.
It is possible to do the outbound process in much less space and much less time, but with the disturbances this could result in chaos with much lost goods. These disturbances should first be brought back to a minimum. Then it is possible to return to less than half the space that is used now.

9 Implementation plan

In order to reduce the amount of space needed before July 2015, certain steps need to be taken.

9.1. Getting a grip on disruptions before returning

If Damen wants to return before July 2015, they have to start immediately with minimizing the disruptions in the process. A lot of the amount of space that is taken in the central warehouse is there because storage within Damen is free. The warehousing is paid by input and output transactions and what happens in between is left out. So if goods are delivered one year too early, this is a problem for the central warehouse, but not for any other party. The supplier gets paid and the goods are in time for the shipment (so the project manager is satisfied). By billing the services delivered by the central warehouse according to the actual costs of those services, a form of feedback is given. Early deliveries will create costs for the project manager, which will try to avoid this for the next delivery. This is no punishment, just an insight into the real costs that are made by decisions and problems that have come up outside of the span of control of the central warehouse. This will also make the alternative to store goods within Damen opposed to storing them at the supplier a fair one. The realistic costs for storing there or here are weighed and the best alternative is chosen. At the moment the only alternative is storing them within Damen since this is considered free. If goods will no longer be used, this would become an issue much faster. Now they are forgotten until somebody brings it up, but if these goods are put into the attention of parties with the jurisdiction to do something with the goods because they will cost money, they will be sold, shipped or put into free stock much sooner.

Using a few examples within the Damen central warehouse the issue can be clarified.

Unnecessary goods


Figure 9.1: Canceled goods

The three screws in figure 9.1 were replaced by another type of propulsion and thus became unnecessary. They arrived at the central warehouse around August 2008 and never left. They have a diameter of two meters and are not easily stored more efficient than this. Screws are mostly designed for one specific boat in a specific region in the world, so there is a large chance that they will never be used. There seems to be no reason to do anything about this and although this is a problem for the central warehouse, there is no financial compensation for this. If the amount of space that it uses and the amount of time it is there would be billed, this problem would have been solved already. For a successful return to the previous warehousing facility, Damen should decide if it wants a distribution center or just a storage facility. The space is large enough to use as a distribution center for the flows through it, but not large enough to keep storing a large amount of goods that are not linked to shipments that are leaving any time soon.

On hold

There is a large amount of goods that is put 'on hold' within Damen Shipyards, of which all the goods in figure 9.2 are an example. This could be because the customer is not paying (yet) or one of many other reasons. This causes enormous amounts of goods to be stored indefinitely. If this is how Damen wants to operate, they will need the larger space to be able to handle these peaks in space requirements. Again, this storage is not billed and the income for the central warehouse thus does not represent the services that they deliver.

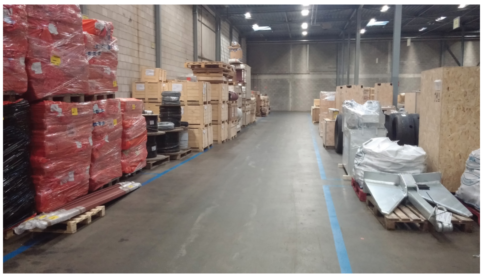


Figure 9.2: Goods on hold

On hold (DTC[1])

Figure 9.3: Goods that are on hold

As was mentioned in the previous example, the goods that are 'on hold' create a large disruption in the process. For DTC projects this is also a large problem in the outbound section. The customer demands to inspect the goods before they are shipped to their yard. The problem in this is that the goods are all laid out over the floor (categorized) so that they are easy to inspect, but the customer often postpones their visit with numerous weeks. This causes a large part of the outbound area to be filled with goods that are on hold. In May 2014, this was more than 1500 m^2 (all the goods that can be seen in figure 9.3). The inspection date should be final as soon as the outbound work begins, this would reduce the severity of the problem since the goods are then not laid out all over the floor. If the goods are stored according to the categories in which they are inspected, the goods can stay in storage until the very moment they are inspected, also reducing this problem.

Storage

Figure 9.4: Dedicated storage location

The service department has started a type of repair project that requires all goods to arrive before they are shipped. This is logical, since it saves shipping costs. An area in the warehouse is dedicated for only this project and nothing else can be put there. Because the arrival date of these goods is so scattered, this means that if one package is too early (as can be seen in figure 9.4), an oversized area is reserved.This type of space usage is very inefficient and should be solved. The suppliers should be

[1]Damen Technical Cooperation provides a building kit to build a Damen boat at a non-Damen shipyard

contacted to deliver on the moment the last items can be delivered, since demanding it earlier will cause this kind of space to be used inefficiently.

9.2. Designing the new central warehouse

When the disruptions have been brought back to a minimum, a return can be realized by changing a few things inside the span of control of the central warehouse. These have all been extensively discussed in this report but will be summarized here.

The inbound section has many workstations and many categories in which the goods are divided. With this amount of workstations, even when there are no incoming goods, a lot of space is used. With only one incoming goods lane in stead of fifteen, the capacity is fully used. By placing the workstations around this checking lane, the space that now lies between the checking lanes is no longer wasted. Large goods take up the most space and have the least work (if they consist of only a few order lines) and should be brought to the storage immediately so that the incoming goods section can stay small. These large goods can then be checked with the existing handheld terminals. By using a conveying system for pallets, the checking lane is optimally used. Undriven roller conveyor systems (figure 9.5) are available new and secondhand[2] between 50 and 200 euro per meter. The size of the conveyed buffer can be found out by simulating it in practice. The rolling can be simulated by continuously pushing the pallets forwards with a fork lift truck and the workplaces do not have to be around the buffer to simulate that. This pilot study should be done before returning to the previous warehousing facility.

Figure 9.5: Example of a roller conveyor
Source: http://www.businessmagnet.co.uk/images/cobalt_pallet.jpg

The storage can be improved by using a second story for small goods in which the racks are placed with narrow aisles (figure 7.11 on page 54). This will cost around 100 euro[3] per square meter and less than 500 square meter will be sufficient.
The long goods can be stored in a vertical carousel (figure 7.12 on page 54). An exact price has not been found but is estimated on 150.000 euro[4].
Heavy goods can be stored under racks so that the height of the warehouse can be used (figure 7.14 on page 56). This could be implemented now but is not necessary because there is enough space.

The outbound section should separate the staging and the picking task so that the goods can be picked as soon as they are put into the staging area. To ensure the picker has enough goods to process, a two-bin system could be used. As soon as the staging area is empty, the picker has enough work to proceed but this gives the stager the signal to get more goods from storage. To effectively use this system, the size of the goods should be known so that an estimation can be given of what fits together into a crate or a bundle so that the picker gets the right types of goods every time. If the picked goods would have a location, they could be stored efficiently so that less floor space is used. This last part should be put into practice (by making a request for change for the software used) before returning to the previous warehousing facility.

[2] http://www.tweedehandsrollenbanen.nl/rollenbaan_gebruikt.html
[3] http://www.logistiektotaal.nl/achtergrond/extra-vierkante-meters-voor-weinig-geld/
[4] The estimation is based a more than seven meter high secondhand vertical carousel that is offered for 28.700 dollar on http://www.sjf.com/vertical_carousels.html. The load per shelve would be higher, it would be wider and probably new

10 Conclusions

The central warehouse of Damen Shipyards in Gorinchem was too small to handle the flow of goods without causing a decrease in its performance. As a temporary solution a new facility was found nearby, offering three times the amount of space of which the first two years rent would be for the price of one. They had planned to return to the old warehousing facility before the third year, which should give them enough time to find a way to handle the flow in a way that requires less space. The research assignment was to look for ways to fit the process of the larger new warehouse in the previous warehousing facility without returning to a process prone to errors.

So what causes the need for so much space? As has been stated in this report, the space usage can be divided into three parts:

- The receipt of goods, now taking up 4200 m^2
- The storage of goods, now taking up 8200 m^2
- The consolidation and shipping of goods, now taking up 6400 m^2

To fit this into a facility offering 6700 m^2, changes will have to be made. The changes are divided into answers to the research question and its subquestions. The research question is:

'What can Damen change in the order flow to reduce the amount of goods in the central warehouse and how can these goods be handled more efficiently within the central warehouse so that a return to the previous warehousing facility is made possible by July 2015?'

Which will be answered after the subquestions are answered in the coming sections.

10.1. Reducing the amount of goods in the central warehouse

'How much more efficient can the space be used if incoming goods are delivered in time and how can this be reached by changes in the organizational structure?'

If goods are delivered in time, meaning they arrive when they are actually needed to be shipped in time, there would be no need for storage at all. With this predictability, the capacity of the process can be taken into account and the input and output could be planned accordingly, or the manpower can be divided to be able to process the peaks faster and with less space usage. This can be reached by using feedback and feed forward. Feed forward does not actually change the input, but can improve the predictability and the time needed for receipt. Feedback can be provided by including the storage time in the way warehousing is billed. This would give a more realistic price for the delivered services. The costs for long periods of storage will then give a signal to either ship the goods, sell them, or avoid the problem for the next time. If this is the supplier's wrongdoing, the responsible parties within Damen can contact them to resolve this. Currently nothing is done to prevent early deliveries.

10.2. Receipt of goods (4200 m^2)

'How much more efficient can the space for incoming goods be used by changes in the method of work and how can this be accomplished?'

In this part of the warehouse, the goods are received, checked and then put into storage. These steps should ensure that the goods can be processed further without delay. The incoming goods section consists of 4200 m^2 of which a lot of space is not used directly for the receipt of goods. This includes:

- Facility storage 1180 m^2 is reserved for this, but less than 200 m^2 is used for the receipt of goods. The rest is used as storage for archives.
- Erroneous goods 390 m^2 is used to temporarily store erroneous goods. All goods that do not have the right papers, are damaged, or are in any way not fit to be processed further will be put here. On average it takes quite some time to handle these properly. If this situation is improved and if these goods are stored more compactly, this could be done in less than 200 m^2.
- Interaction area Although this area (355 m^2) is used for the receipt of goods, it will not be necessary upon return to the old warehousing facility as most of it is used to enable transport between the two warehouses.
- Receiving goods This area (2215 m^2) is directly used to check the goods. There are fourteen checking lanes and one area for large goods. These are not always fully filled and the goods are added on the back of the row while the front is being handled. Without a roller conveyor this means that the space per checking lane is used inefficiently. Furthermore the fourteen workplaces are never used on the same time, so this is also a waste of space. The area between the checking lanes is also space that cannot be used for anything else and is not used for the receipt of goods.

By going to a system in which only one checking lane is used with a roller conveyor around which only eight workplaces are placed, the receipt of goods can go back to 1200 m^2. This is because there is no wasted space between the checking lanes, the front of the lane is always filled, and peaks will be handled by adding manpower without stationary workstations.

10.3. Storage (8200 m^2)

'How much more efficient can the storage space be used by changes inside the central warehouse and how can this be accomplished?'

Because goods come from many different suppliers, they need to be consolidated. To allow for some difference in delivery times and process times, storage is needed.

Because of the categorization according to the customer's location, certain areas will remain empty until something comes in. This effect is called honeycombing and is widely present in the central warehouse. In addition to this, the height of the racks is not used where possible and the area above large goods is not utilized. Furthermore, small goods are unnecessarily placed in very wide aisles, causing additional inefficiency in space usage.

By placing large and heavy goods in the same area as the other project-specific goods, the racks will be better utilized and the square meters available will be used much more efficiently because the height above these large and heavy goods can be used. By placing the small goods in two stories of narrow aisles would allow for all small goods (a little less than half of all order lines) to be stored in only 500 m^2. If long goods are placed in a vertical carousel, the height of the warehouse will be used. All long goods could then be stored in less than 100 m^2. All other goods should then fit in less than the current amount of space used for racks, based on how much they are filled now, the extraction of small goods from this section and the use of the floor space for heavy goods. The total would come down to less than 3000 m^2.

Since the average time between the moment the goods are placed in storage and the moment they are picked is 8,67 workdays, there are continuously 8843,4 lines in storage. This is caused by the steps between the planning and the warehouse. By improving these steps, the amount of lines in storage could be reduced to less than what comes in in one day (1020 lines). If the buffer in the planning is not removed, this improvement could reduce storage to only three days worth of goods. Being able to predict what comes in per day could also enable the categories for goods in storage to be altered on a daily basis, which would use the storage space more efficiently by reducing the effects of honeycombing. If the improvements in the way goods are stored are combined with the reduced time in the system, the goods could be stored in less than 1000 m^2.

10.4. Creating shipments (6400 m^2)

'How much more efficient can the space be used for the outbound process by changes within the central warehouse and how can this be accomplished?'

In this part of the warehouse, the goods are retrieved from storage (staging) and are subsequently consolidated (picking) together. These packages of goods are often crates and bundles. These are then made ready for transport (packing).

Goods are first staged until there is an appropriate amount to form a shipment. They are then picked in an adjacent area and then when completely finished they are moved to a location to wait for transport. This step-by-step method of work, combined with the fact that all these steps take quite some time causes a large amount of space to be used.

If a more continuous flow is introduced by using a two bin system, the amount of space per item can be halved since the goods that are taken from storage would directly be processed further in stead of first gathering all goods and subsequently processing it in another area. If the staging step would be skipped altogether, the process could work with even less space. Because the administrative step has been improved drastically by this research, the amount of time needed for this process is brought down and this will already show positive results on space usage since the throughput time will be reduced. Without the staging step, the outbound process could be done in less than 2000 m^2 if the amount of goods that is put on hold is under control. If not, more space will be needed to be able to store these goods.

10.5. Return to the old warehousing facility (6700 m^2)

'What can Damen change in the order flow to reduce the amount of goods in the central warehouse and how can these goods be handled more efficiently within the central warehouse so that a return to the previous warehousing facility is made possible by July 2015?'

Untimely deliveries cause the amount of goods in the central warehouse. Early deliveries can cause the average storage time until the goods should be shipped to increase, and late deliveries can cause the shipping date to be postponed and can thus increase the average storage time. If the spread in arrivals is large enough, multiple shipments will be formed which will bring forth additional costs. The average storage time is directly linked to the amount of goods in the central warehouse.

There is no clear feedback on the actual consequences of untimely deliveries and relevant parties within Damen have no reason to change anything about this because (for early deliveries) 'at least then we'll have it' and the storage within Damen is only paid per inbound and outbound transaction, not by amount of storage or storage time. By adding a feedback loop to the order flow in which the actual (financial) consequences of these deliveries for the central warehouse are fed back to the relevant parties, they get the chance to improve.

Once the goods arrive at the central warehouse, they are received, inspected, stored, staged, picked, packed, and transported to the customer. All these steps are set up with quite a lot of space in the new warehousing facility, offering no incentive to find an alternative that uses less. The objective that was set that this move would only be a temporary measure to find out a way to continue with less space requirements is thereby made implausible.
It is however possible to handle the current flow of goods through the central warehouse in only 6700 m^2. The receipt of goods can be done in less space by going back to only one checking lane to inspect the goods (with all the workplaces around it) and by placing large goods directly into storage in stead of placing them with the other incoming goods. The storage can be done more efficiently by using the height of the warehouse and by having appropriate aisle widths. The outgoing goods can be handled in less space. To do this, the disruptions[1] will have to be under control before a return in July 2015 is possible.

[1]The main disruptions are goods that are on hold, canceled, delayed, lost, much too early or too late

11

Recommendations

Although this report was written to give a wide view of the possibilities for space reduction in the central warehouse, there are some areas that could be topic for future research. A few pilot studies have been suggested, by doing this the human aspect of a change can be taken into account. It also helps in finding problems with the implementation. Furthermore a thorough cost analysis should be made for the implementation of a plan to go back to the previous warehousing facility. Damen requested a research on how they could go back before July 2015, not how much this would cost. The study still tried to find ways to improve with low investments and that could be implemented in the limited amount of time. A lot of the improvements do not directly cost money, but require more control over the flows through the central warehouse. It could be that more expensive solutions offer greater advantages in the long run, which should be researched for future workings of the central warehouse.

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A

Scientific research paper

Increasing the efficiency in space usage for the Damen Shipyards central warehouse in Gorinchem

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Abstract

Damen Shipyards wants to do be able to handle the flow of goods for boats built all over the world in their central warehouse offering 6700 m^2 but has been struggling to do so. They planned a temporary move to a location offering almost thrice that in July 2013, but with a rise in rent coming up in July 2015, time is running out for them to find ways to improve. What can Damen do to reduce their space usage? By analyzing the elements adding to the needed amount of space with the Delft Systems Approach and by finding ways to make them more efficient in space usage, a plan to go back has been made with success.

1. Introduction

Damen Shipyards is a Dutch family-owned company that is represented with shipyards all over the world. A large variety of materials for more than 150 delivered boats a year are shipped through the central warehouse (CW) in Gorinchem. The rising flow of materials became problematic for the CW and in July 2013 the decision was made to move to a location three times as large (6700 m^2 to 18800 m^2) for two years. In that time they should be able to improve the processes in such a way that they could once again be handled in the old warehousing facility.

This paper offers ways to reduce the required amount of space after a move. It is applied to the new warehousing facility, but could be applied to other warehouses as well.

2. Method

The processes that are directly connected to the central warehouse have been analyzed by first depicting the multi-aspect model as a PROPER (PROcess PERformance) model [1]. Then the order flow (as a function within the model) has been analyzed to determine the formation of the inputs and outputs of the CW. Within the CW, the functions were split into three parts that have a strong space consuming character. Possible issues were quantified with the help of extensive data research (the data was gathered from IFS Applications and processed in Microsoft Excel and Microsoft Access) validated by intensive checks of the data on the the process.

3. Findings

The PROPER model is simplified and the functions that do not have direct or indirect influence on the space usage, as well as the space usage itself, are left out (Fig. 1). The consolidate function is done within the warehouse and contains the receipt of goods, the storage, and the creation of the shipments. What comes in and goes out of the system is decided by the function that handles orders.

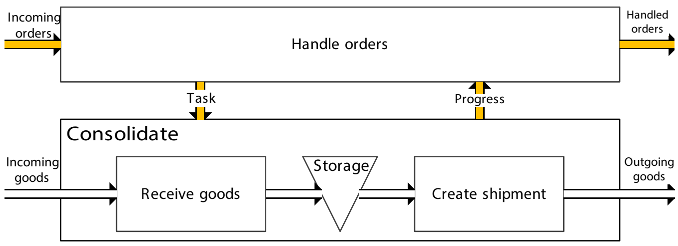


Figure 1: Simplified version of the PROPER model

3.1. Handle orders

The inputs and outputs are dictated by the tasks that flow into the consolidate function from the function that handles orders. The tasks are called activities. The input of the CW comes from activity 4.2.1 (Fig. 2). Although this is only one day, data research suggests that less than 18% arrives in the week of that activity (Fig. 3). The actual delivery date only lies in the same week as the date promised by the suppliers for less than 35% of the order lines.

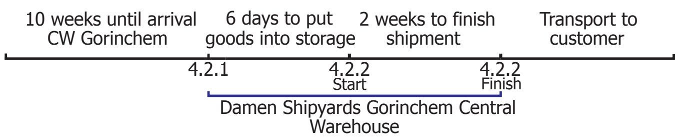


Figure 2: Planning

Because more than 75% of the goods arrive before they should be shipped (the finish date of activity 4.2.2 in Fig. 2), the perceived problem caused by this is much smaller than the actual problem. Which is an average time between inspection

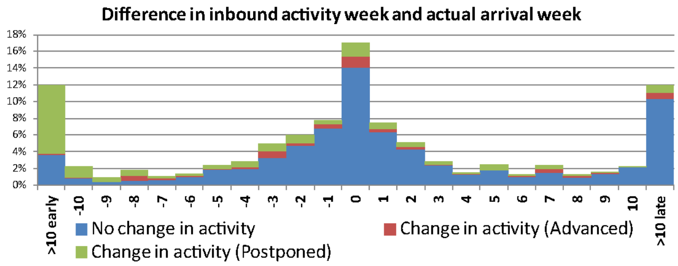


Figure 3: Graph of inbound activity date versus actual delivery date (arrived between week 32 and 51 of 2013) in weeks (negative value indicates the actual arrival week lies before the inbound activity week)

and picking of 8.67 workdays. With Little's Law (Eq. 1) and using the average of 1020 order lines that arrive per workday this means that there are more than 8843 order lines in the system between inspection and picking. By reducing this, the amount of space needed for storage would become much less (the largest part of the CW in Fig. 4 consists of storage). Because the input is so unpredictable, the CW is also unable to actively react to peaks in incoming goods.

$$L = \lambda W \tag{1}$$

Little's Law [2] where:

- L: expected number of items in the system
- $1/\lambda$: expected time between two consecutive arrivals to the system
- W: expected time spent by an item in the system

Goods must be linked to an outbound activity to be shipped. If goods arrive without an activity or if they lose their activity (because they are canceled), they stay in the central warehouse until someone sends the task to the consolidate function to do something with it. The CW is full of items like this and because the CW is paid according to their input transactions and output transactions, there is no compensation for the amount of storage they use.

3.2. Receive goods

The amount of space that can be saved in the incoming goods section can be analyzed in a number of ways. The largest area for this section within the CW is taken by the queues for inspection (receiving goods in Fig. 5). There are fifteen queues with fourteen workplaces to handle them. Every workplace mainly handles the goods from one queue and the queues themselves are categorized. Because the amount of goods that arrive per categorized queue can vary, some queues will be fuller than others, and some might even be empty. This results in capacity being lost and thus an increased throughput time. This effects the number of order lines in this system and thus the required size of the queues. The queues do not have a conveying system so the front can be empty while goods are added to the back, this also creates unused space. The area between the queues is unused as well.

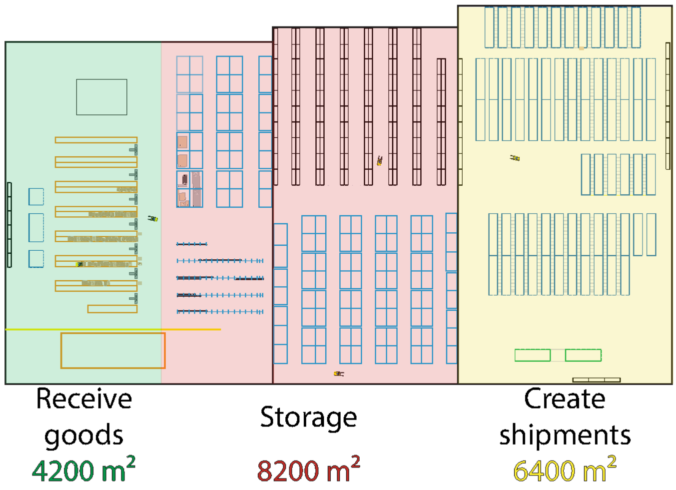


Figure 4: Layout of the current central warehouse in Gorinchem

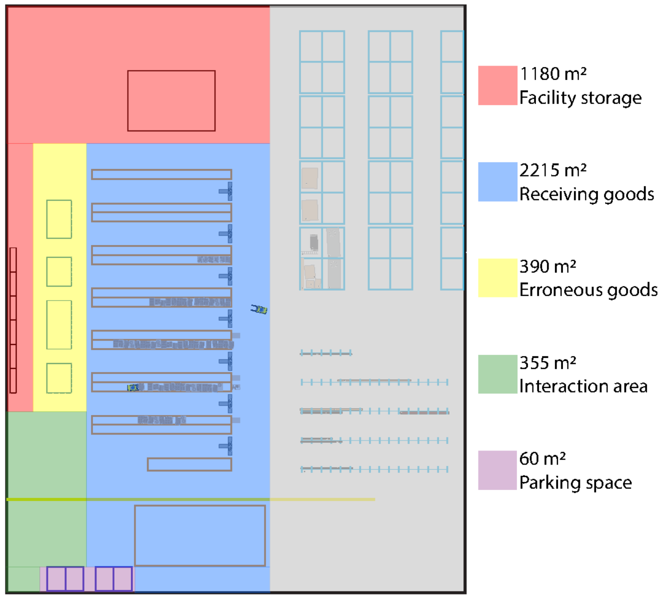


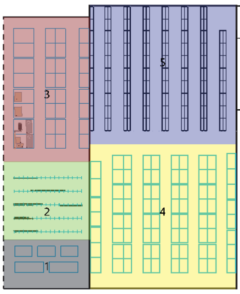
Figure 5: Layout of the incoming goods section

The incoming goods section also stores many items that are not needed for the receipt of goods. This is a luxury, but there is no room for it in a smaller warehouse. The erroneous goods section is used to put all items that for some reason cannot be handled further in the process. Possibly because they are not easily identifiable or damaged. The interaction area was added to handle transport between the two warehousing facilities.

Another way of saving space is by speeding up the process. The most time is needed for identification of the individual order lines. The amount of fixed workplaces and queues also seems higher than necessary. In the period between 2 and 13 September, on no occasion were there more than eight unique ID's doing work there.

3.3. Storage

In the storage area, the efficiency in space usage can be expressed by looking at the number of order lines per square meter [3, 4]. Although this does not take the variety in size of the order lines into account, it can work as reference for improvement. On average, the efficiency in space usage was measured over four measuring days and is 0.99 order lines per square meter for the entire storage area (Fig. 6). The least efficient (an average of 0.30 order lines per square meter) is the long goods since the cantilever racks used are only two meters high. Long goods are handled by side loaders that need less aisle width since they have no turning cycle. Hereafter comes the inefficient storage for large and heavy goods (an average of 0.69 order lines per square meter), since the height above them is not used, and the aisles are quite wide. The racks (1.84 order lines per square meter) could be used more efficient because of negative honeycombing effects (areas are reserved for specific yards, causing them to be empty if there is no input for that yard, pallet places are reserved for a specific shipment, causing the pallets to be often filled with only one small parcel). The small goods could be stored more efficiently because they are now placed between the other goods in the racks (aisle width 4.5 meter) on a full pallet place (Fig. 7). Data research suggests that around 47% of the order lines are between 0 and 2 kilogram, and 48% of the complete purchase orders are under 12 kilogram. These both indicate that a large portion of the parcels in the central warehouse could be lifted by hand and does not have to be moved by fork lift truck. As a result, the aisles could be less wide.



Category	Area (m^2)	2013-10-24 Lines/m^2	2013-12-02 Lines/m^2	2014-02-14 Lines/m^2	2014-03-05 Lines/m^2	Average
1	530	0,03	0,00	0,17	0,34	0,14
2	870	0,24	0,21	0,39	0,36	0,30
3	1600	0,26	0,71	0,64	1,31	0,73
4	2600	0,57	0,57	1,02	0,62	0,69
5	2600	1,91	1,57	2,04	1,86	1,84
Sum	8200					
Average		0,86	0,84	1,14	1,10	0,99

1 Very large goods
2 Long goods
3 **Services (floor storage)**
4 **Heavy and large goods (floor storage)**
5 Normal sized goods (racks)

Figure 6: Storage areas with categories, area, and efficiency

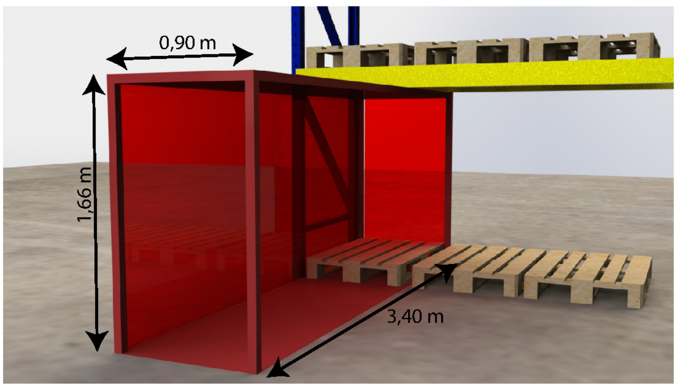


Figure 7: Area reserved for one pallet in the storage racks

3.4. Create shipments

The creation of shipments is started by reserving the goods from storage. After this, the goods can no longer be moved and IFS indicates that the reserved items are no longer available at their location. After that, the goods are staged, which means that they are retrieved from storage and put into a staging area (which has the dimensions of a twenty-foot container). This is done until either all goods have been staged, or enough has been staged to fill an entire shipping container (this is estimated by the stager). The goods are subsequently put into seaworthy packaging units which is called ‘picking’, which is done in an adjacent area, also the size of a twenty-foot container. When all goods have been staged and picked, or when more of the shipment would not fit in a shipping container, the goods are put into a third area from which they will be packed into the shipping container. Every administrative step takes an average of 23 seconds and is even seen to be 90 seconds. This has to be done for every order line which slows down the outbound process by a lot.

4. Conceptual redesign of processes

4.1. Handle orders

By supplying feedback from the consolidate function in the CW to the function that handles orders, the input and output could be influenced to better fit the capacities of the central warehouse. This can be done by changing the way the CW is paid for its services. If the amount of storage and storage time are billed, there is a strong incentive within Damen to take action. If goods are put on hold by the handle orders function, that is a service the CW provides that should be paid for. If the supplier would be to blame for a very early delivery, this can be resolved by the responsible parties within Damen, since the CW has no right to talk directly to the suppliers about this. Every workday that the goods are closer to the day they are actually needed, more than a 1000 m^2 less would be necessary for storage (if the 0.99 order lines per square meter was upheld).

If the suppliers provide better feed forward towards the central warehouse, the peaks could be handled without using much more space (at the receipt of goods). If the planning is accurate, the peaks could even be avoided by using a maximum number of arriving order lines per workday.

4.2. Receive goods

By placing the workspaces around one larger conveyed queue, the space is used much more efficiently. The use of capacity is increased because the number of distinct queues is brought back to only one. The area used even if no goods arrive (because of the space reserved for the queues) is reduced, and the area between the queues is made obsolete. The front of the queue would always be filled because it is conveyed and the fixed amount of workplaces could be brought back to eight, with the option to use the already existent hand-held terminals in stead of desktop computers to inspect the goods during busier periods. The exact size of this one queue should be analyzed by Damen with a pilot study. Using only one, longer queue and the same size for the workplaces, this could probably fit in 600 m^2. The space for erroneous goods could be reduced and the area for interaction with the other central warehouse would be unnecessary. With only the facility storage that is needed for the receipt of goods, the total space usage for the incoming goods would come down to less than 1200 m^2.

4.3. Storage

By storing the long goods in a vertical carousel, the height could be utilized and less than 100 m^2 would be needed for long goods storage in stead of the 870 m^2 it uses now.

The section above the heavy goods could be used by storing them under the racks where possible (Fig. 8) and in the racks if they are not too heavy and not too large. This is technically possible and makes almost the existing entire heavy goods section obsolete. This allows for a decrease of almost 2600 m^2 and an increase in efficiency if the space above the other heavy goods would be used for a second story or a higher rack.

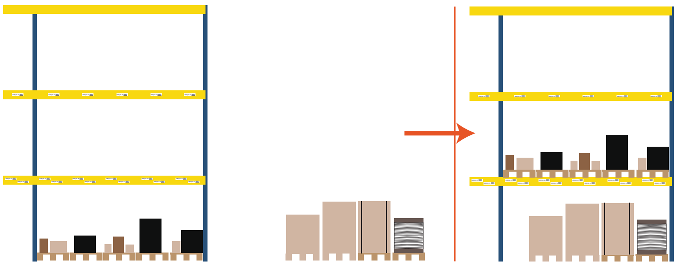


Figure 8: Concept for more efficient storage above heavy goods

By storing the small goods separately, the amount of racks needed for other goods could be decreased. Around 4000 parcels (sometimes containing multiple order lines) weighing less than 12 kilo could be stored in 500 m^2 by eliminating the need for wide aisles (Fig. 9). The height of the warehouse could be utilized by using a second story in the racks. The honeycombing effects for these goods can be eliminated by using random storage in stead of dedicated storage.

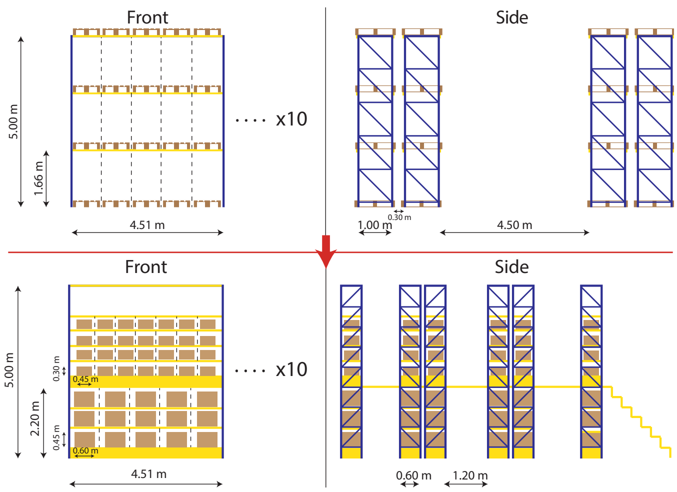


Figure 9: Concept for more efficient storage for small parcels

4.4. Create shipments

The step by step method of work that is used needs a lot of space. By picking goods directly after staging them (with two different people), the total amount of space that is needed is halved. This could happen by creating a small area that is representative for enough work to continue picking. If this area is empty, the stager would get a signal to fill up this area again.

5. Conclusions

The amount of goods in the central warehouse is partly caused by the planning (the six days in Fig. 2). It is worsened by the failure within the organization to have these goods ordered for the exact date and from the supplier to deliver according to what they promise. The fact that storage is only billed according to the input transaction and the output transaction makes the responsible parties within Damen unwilling to change anything about this, since early deliveries have no negative consequences for them and ensure that the goods are shipped in time. By changing this, a return to the previous warehousing facility can be made possible. Inside the previous warehousing facility, the processes have to be improved. Less queues and less workspaces can be used and by placing them around the queue in stead of in front of every one of them, the amount of space used for incoming goods can be brought back to 1200 m^2. By storing small goods in small aisles, long goods in a vertical carousel, and heavy goods under racks increases the efficiency in such a way that even without changing the amount of goods in the CW, this could all be done in 3000 m^2. Creating shipments can be done with half the amount of space by creating a better flow between staging and picking. By speeding up the administrative process, this could even be done in just 2000 m^2. As a result, they only need 6200 m^2, allowing a return to the old warehousing facility offering 6700 m^2. The CW does however have a large amount of goods that come in but will not leave soon, or ever, if these disruptions are not handled by the organization, even this larger warehouse will soon be too small.

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