Improving the Logistical Process Around Cross-Docking of Products from Packaging Lines
A Case Study at the Zoeterwoude Brewery of HEINEKEN Nederland Supply
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Improving the Logistical Process Around Cross-Docking of Products from Packaging Lines

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by

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in partial fulfilment of the requirements for the degree of

Master of Science
in Transport, Infrastructure and Logistics

at the Delft University of Technology,
to be defended publicly on Monday October 5, 2015 at 2.30 PM.


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An electronic version of this thesis is available at http://repository.tudelft.nl/.
Preface

This thesis is written as a completion of the Master of Science Transport, Infrastructure and Logistics at Delft University of Technology. Making this thesis triggered me to apply the theory from both my Bachelor and Master within a practical environment. It provided me with valuable experience that is never obtained from a purely theoretical research. This opportunity made me more aware of real business problems and is therefore a highly appreciated input for my further career in consulting. I would like to thank Bram Smits and Pieter Hoondert for giving me this exciting assignment. I would also like to thank Pieter Hoondert for his supervision during the project. There are many other colleagues within HEINEKEN that were indispensable for a successful completion of this report. Many thanks to all of them.

Prof.dr.ir. A. (Alexander) Verbraeck, Ir. M.B. (Mark) Duinkerken and Dr. H.K. (Heide) Lukosch have assisted me to guarantee an academic and holistic research. I would like to thank them for their valuable feedback and tips during the entire period, but especially for their personal coaching during the final phase of the project.

I would especially like to thank my family, friends and girlfriend for their interest and support during my entire studies. Without their encouragement, motivation and feedback I would not be able to reach the point at which I am at the moment and be the person I became.

S. R. IJs
Delft, September 2015

The difference between a successful person and others is not a lack of strength, not a lack of knowledge, but rather a lack of will.

Vince Lombardi
HEINEKEN Nederland Supply continuously strives to improve its logistical processes in order to be able to serve its customer better, but at the same time to reduce costs. Within the Zoeterwoude Brewery, the Customer Service & Logistics department is responsible for the supply of the materials to the packaging lines, but also for the loading process of the pallets arriving at the warehouse. Increasing output from the packaging lines have caused regular spill-back of finished goods towards packaging line 2, 4 and 7. This spill-back causes standstill of the filling machine and therefore a drop in the performance of the packaging lines. HEINEKEN Nederland Supply has a large number of open sales orders and is already producing in over-time. This means that every lost production hour leads to sales losses for the company and the potential loss of valuable customers. The objective is to improve the loading process such that the capacities and planning are better aligned with the supply of the packaging lines. This leads to the following research question:

*How can the loading process at the Zoeterwoude Brewery of Heineken Nederland Supply be improved such that the capacities within the process and the corresponding planning are better aligned with the supply of packaging line 2, 4 and 7?*

This research is framed within the DMAIC methodology (and performed by following on the Theory of Constraints). This research starts by analysing the current loading process and influencing factors. It is found that the amount of pallets that is being processed by CS&L is growing at a fast rate. Especially the loose-loaded pallets are leading to an increase in pallets. The share of these pallets grew in total from 6% in 2012 to 12% (even 43% for packaging lines 2, 4 and 7) in 2014 and is expected to grow even further. The process is found to be a complex socio-technological part of the brewery and is influenced by many factors, both controlled internally and externally. The next step in this research was to collect data related to this process and to obtain valuable information from different viewpoints. From the analyses the root-causes of the problem are found.

From the bottleneck analysis it is found that the transfer car between the cross-docks and the loading stations is not able to handle certain product combinations entering the warehouse. The capacity of the loading operators is sufficient, although requiring two skilled operators. Unexpected disturbances lead to buffers (cross-docks) being occupied, after which the process is not able to restore itself because of a lack of over-capacity of the transfer car. From the remaining analysis it was found that the unexpected disturbances to the process are problems with the availability of containers, human errors, lack of communication, lack of skilled operators and the lack of warehouse capacity.

The loading process can be improved by reducing the input to the cross-docks. This can be done by limiting the flow from line 41 and 42 by removing the pallets locally. Another solution is to introduce an alternative for the current transfer car that provides a capacity of 263 pallets per hour, such that full advantage of the downstream capacities can be taken in when clearing the cross-docks. Also by connecting the cross-docks with each other, the buffer capacity can be better utilised. The main disturbances can be reduced / eliminated by introducing strict rules and penalties regarding the delivery of containers. Also communication between the planning, packaging and CS&L department shall be more frequently with an end-to-end focus. Besides extra training and increased maintenance on critical machines, more responsibilities for the warehouse coordinator decreases the number of errors made by the operators.

It is expected that 80% of the OPI losses can be eliminated by the implementation of a new transfer car and by better alignment of the downstream processes. This adds up to a yearly non-cash saving of €41,700 for the packaging lines under study. Based on the fact that currently customer orders are being denied due to capacity shortages, these savings may increase. For packaging line 7 only (up to July 2015), a total sales loss of €40,000 was encountered. The increased capacity reduces to time...
to clear the cross-docks (100% occupation of cross-dock 21, 22 ans 7) from almost 7 hours to a little more than 2 hours.
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HEINEKEN Nederland Supply is the production subsidiary of HEINEKEN Nederland for all domestic and export products (beer and cider). In 2013, over 50,000 containers and 20,000 trucks full of beer and cider for domestic and export customers all over the world left the breweries in the Netherlands alone. The production facilities are located at the breweries in Zoutewoude, Den Bosch and Wijlre. The most important products are Heineken, Amstel and Brand. Other more innovative products and packaging that are produced at HNS are Jillz, Wieckse Rosé, but also kegs (HEINEKEN, 2015b). In Figure 1.1, the production process is visualised in a highly simplified way to have an idea about the internal supply chain.

![Production Process Diagram](image)

Figure 1.1: Schematic overview of the production process at Heineken Nederland Supply

HEINEKEN Nederland Supply continuously strives to improve its logistical processes in order to be able to serve their customers better, but at the same time to reduce costs. The improvement process within the company is based on the principles of Total Productive Maintenance (HEINEKEN, 2015b). Total Productive Maintenance, or TPM for short, is an advanced manufacturing technique that focuses on maximizing the overall equipment effectiveness of any asset utilized in the production of goods and services (Wireman, 2004). One of the pillars is related to the logistics. The focus of improvement is mainly on losses within the warehouse, the transport and the customer service. These losses shall be minimised / eliminated. One of the major steps of improvements was the implementation of cross-docking (will be explained later) at the Zoeterwoude Brewery. At the moment there are various challenges within the logistical process that need to be tackled. This research deals with one of these...
challenges, although an important one with a large (cost) impact on the entire process. The challenge is described in Section 1.1. The main research question, along with its supporting sub-questions is formulated in Section 1.3. Finally in Section 1.4 some previous internal research on this challenge will be discussed.

1.1. Problem Statement

Problems are being observed in the final stage of the logistical process following after packaging line 2, 4 and 7 at the Zoeterwoude brewery: placing the finished goods (pallets stacked with filled boxes) in a container. It is observed that, depending on the amount of pallets that are being offered, the logistics department is not able to catch-up with the output of the previous production stages, which causes spill-back further upstream in the production process. This especially holds for the containers that are shipped without pallets (further referred to as: loose-loaded containers): these shipments are mainly transported to countries where automation (use of forklifts) is limited and are unloaded by hand, but also to countries where strict restrictions are in place regarding the import of wooden pallets. At the same time, a higher loading capacity can be achieved for these containers (less shipment of ‘air’). However, these containers have specific loading patterns that require two layers of less high stacked pallets. Since these pallets carry less boxes, more pallets are needed to ship the same volume as with a regular loading pattern. This final stage is for a large part handled by manual operations: picking up the pallets from the conveyor belt, removing the pallets from underneath the stacked boxes and placing the boxes into the container. The logistical process after packaging line 2, 4 and 7 is known as cross-docking.

At this point it is unknown what causes the problem. Although HEINEKEN Nederland Supply looks especially at the capacity constraint of the mechanical loading phase, the problem may however be caused by a combination of socio-technological factors and may therefore be more complex. It is not known if the process (planning) is causing problems or if the process realisation is leading to the symptoms. For example a desired situation could be situation X, whereas the system is designed / planned for situation Y and operates according to situation Z. It is known that a poor planning can lead to excessive inventory levels or back orders and thus increase cost or reduce customer service (Shim & Siegel, 1999). In an ideal case the realisation is equal to the planning and the desired situation (‘Goal’). This idea is shown graphically in Figure 1.2.

![Figure 1.2: Relation between a desired situation, the planning and the realisation](image)

Section 1.2 will provide a short literature study on the concepts of cross-docking and the v-graph theory that is in place at HEINEKEN Nederland Supply.
1.2. Cross-Docking and the V-Graph

An important aspect within the supply chain of HEINEKEN Nederland Supply is cross-docking. Most of the export orders are directly shipped after being produced and stacked on pallets. Cross-docking is a logistics strategy that is used by many companies within different industries. In general, cross-docking is the transfer of incoming shipments directly to outgoing vehicles without storage in between. Cross-docking can serve various goals, such as the consolidation of shipments, a shorter delivery lead time and cost reduction (Apte & Viswanathan, 2000). Traditional distribution centers first receive goods, store them, and ship them when requested by the customer. Storage and order picking are in general the costliest operations in logistics. By improving on one of these two operations costs may be reduced. Cross-docking is an approach that completely eliminates both handling operations (storage and order picking) (Galbreth, Hill, & Handley, 2008) (Schaffer, 1997). A terminal dedicated for cross-docking is called a cross-dock. In practice, most cross-docks are long, narrow rectangles (I-shape), but other shapes are also used (Bartholdi & Gue, 2004). A cross-dock has multiple loading docks where trucks (or containers) can dock to be loaded or unloaded. Cross-docking corresponds with the goals of lean supply chain management: smaller volumes of more visible inventories that are delivered faster and more frequently (Belle, Valckenaers, & Cattrysse, 2012).

Since the products move directly from the packaging line towards the containers, each stage is ‘connected’ to the previous and next stage in the production / logistical process. This requires that the capacities of the stages are aligned with each other. The production process within HEINEKEN Nederland Supply used to operate within a V-shaped capacity diagram (see Figure 1.3) in which the bottom part of the V represents the most critical part: the filling process (100% capacity).

![Figure 1.3: Visualisation of the 'v-graph' (Harte, 1997)](image)

The branches represent: 1) the input materials (upstream of the filler) and 2) the finished goods (downstream of the filler). Each stage in the process should have a capacity that is higher than the previous stage. This ensures that the filling process keeps running and is not starved by material shortages or blocked by downstream processes (packaging / distribution) (Harte, 1997). One of the main Key Performance Indicators (KPIs) at Heineken Nederland Supply is the Overall Performance Indicator (OPI). This indicator is used to measure the performance of the production lines. A higher OPI leads to a higher output of products in the same amount of time. Each logistical stage needs to keep up with this demand of the previous phases at the lowest costs.

The research question and sub-questions belonging to the problem statement in 1.1 and following from the theory in this section are stated in Section 1.3.
1.3. Research Question and Sub-Questions

On the basis of the problem as stated in Section 1.1, the following research objective can be formulated:

*How can the loading process at the Zoeterwoude Brewery of HEINEKEN Nederland Supply be improved such that the capacities within the process and the corresponding planning are better aligned with the supply of packaging line 2, 4 and 7?*

This thesis is set-up as a broad framework to analyse a similar company that uses the principle of cross-docking. The research question is specifically tweaked to find the root-causes and solve the problem at the Zoeterwoude Brewery of HEINEKEN Nederland Supply, however the methods that will be used during this research can be used for any logistical process following after a supply of materials / finished goods, within different industries.

In order to be able to answer this question, several sub-questions are formulated. These questions help in finding causes to the problem by analysing the current situation, look at different scenarios and tries to obtain new insights to solve the problem. The sub-questions are the following:

- How is the current loading process organised and what factors are of influence on it?
- What data need to be analysed in order to find potential bottlenecks?
- What are the theoretical capacities within the loading process?
- What are the causes of the spill-back from the warehouse to the packaging lines?
- What changes lead to increased system performance and reduced spill-back?

Previous internal research has been done on the loading process for line 2, 4 and 7 at HEINEKEN Nederland Supply. The outcomes are described in the Section 1.4.

1.4. Previous Research

In this section a brief summary of previously done internal research will be provided. Afterwards a reflection on this research is given, such that new research openings can be identified.

1.4.1. Internal Research

At the end of 2013 / beginning 2014, an internal study was performed on the mechanical loading process at HEINEKEN Nederland Supply. This study was performed by van der Heide (2013) and was focused on the technical capacities of the filling process up to the mechanical loading process. Van der Heide concluded that the capacity of the mechanical loading stations is technically sufficient (149% of the filler capacity). Note: The filler has a theoretical capacity of 100%, a capacity of 149% means that the particular chain requires 49% less time to handle the same amount of products than the filler does.

The final stage of the mechanical loading process is performed by manual operations. These manual operations have an average capacity of 117% of the filler capacity. It was mentioned that a capacity of 130% is desired in order to prevent / guarantee a quick removal of spill-back. A few possibilities to achieve this capacity are considered: adding an additional forklift driver, increase driving space or rearrange the tasks of the driver. These solution directions are not implemented yet. Another possible solution that was provided was to increase the loading capacity of the containers. This decreases the number of pallets (pallets can now be stacked higher), and therefore decreases the amount of times that the capacity is insufficient.

Van der Heide calculated the capacities of the individual stages from the filler towards the warehouse. He measured the time it took every stage to process a pallet (or equivalent amount of bottles) and at the same time shoot videos that were later used for analysis. Van der Heide mentioned the importance of repeating previous research, since processes and machine settings could have changed over time (personal communication, March 13, 2015).
1.4.2. Reflection
The internal study was performed at the end of 2013. Since then the capacity of the production line, the product combinations and other factors might have changed. The research accounted for average planning speeds of the production lines. Internal studies also demand for a 130% capacity of the loading facilities in order to be able to catch up after downtimes. It is however not known how this percentage was obtained exactly so additional research is needed. In an ideal case there is no need for additional capacity. The research also lacked a cost trade-off in which the costs for downtime or additional pallet movements were measured against the costs for new machines.

1.5. Report Outline
This report is structured as follows. The system under study will be described in Chapter 2. Next, in Chapter 3 the tools and techniques required for this research will be presented. The process analysis and data collection is carried out in Chapter 4. Following the data collection, Chapter 5 will provide thorough analyses on these data. From the analyses, potential improvements for the most important root-causes are presented in Chapter 6. In Chapter 7 a detailed conclusion, including brief answers to the research question and sub-questions will be given. Finally, in Chapter 8, recommendations regarding this research are given.
The main focus of this chapter is to get some grip on the current loading process. It will answer the first sub-question of this research:

*How is the current loading process organised and what factors are of influence on it?*

Within HEINEKEN Nederland Supply (further referred to as: HNS) the following departments are present: Customer Service & Logistics (further referred to as: CS&L), Supply Development & Support, Purchasing, the breweries and the TPM Office (HEINEKEN, 2015c). It is important to know what packaging lines are supplied by and deliver to CS&L. The packaging lines at Zoeterwoude are described in Section 2.1. Section 2.2 will cover the organisational structure of CS&L. In Section 2.3 the export pallet movements processed by CS&L are described. Only part of the export area is under study. The layout of this export area is described in Section 2.4, the process related factors are discussed in Section 2.5 and finally the process itself is described in Section 2.6.

### 2.1. Packaging Lines Zoeterwoude

In this section an overview of the production lines of the Zoeterwoude Brewery of HNS is provided. Although this research focuses on the system after the production lines, it is important to see what type of products are produced on each line and where the output is being used for (domestic or export). Each production line carries one type of product (although many subtypes may be produced) and is part of a department. The production lines may be equipped with multiple filling machines and have their predefined filling capacity. The production lines are shown in Table 2.1.

<table>
<thead>
<tr>
<th>Line</th>
<th>Product</th>
<th>Destination</th>
<th>Capacity [l/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/12</td>
<td>Returnable bottles</td>
<td>Domestic</td>
<td>16.000</td>
</tr>
<tr>
<td>2 (21 and 22)</td>
<td>One-way</td>
<td>Export</td>
<td>40.000 and 27.750</td>
</tr>
<tr>
<td>3</td>
<td>One-way</td>
<td>Export</td>
<td>84.000</td>
</tr>
<tr>
<td>4 (41-43)</td>
<td>Draught / Air kegs</td>
<td>Domestic / Export</td>
<td>2.700 each</td>
</tr>
<tr>
<td>51</td>
<td>One-way</td>
<td>Export</td>
<td>80.000</td>
</tr>
<tr>
<td>6</td>
<td>Cans</td>
<td>Domestic / Export</td>
<td>60.000</td>
</tr>
<tr>
<td>7</td>
<td>One-way</td>
<td>Export</td>
<td>80.000</td>
</tr>
<tr>
<td>8 (8.1 and 8.2)</td>
<td>One-way</td>
<td>Export</td>
<td>130.000</td>
</tr>
<tr>
<td>9</td>
<td>Returnable kegs</td>
<td>Domestic</td>
<td>900</td>
</tr>
</tbody>
</table>

The above shown packaging lines are closely related to the CS&L department. As mentioned earlier, CS&L provides the input materials, but also receives the finished products that come from these packaging lines. The next section will provide more insight in the tasks and responsibilities of CS&L.
2.2. Customer Service & Logistics (CS&L)

CS&L is one of the main departments within HNS. CS&L is strongly international focused. Over 70% of the products produced by HNS are transported abroad. This department consists of five sub-departments. Although these departments are mentioned separately, on a day-to-day basis they are largely interwoven with each other (HEINEKEN, 2015a).

- **Market Demand & Product Change Management**
  
  Market Demand Management stays in close contact with customers all over the world. This department estimates the worldwide demand and future market changes for the products produced by HNS. The core business of Product Change Management is to take care of the processes around the introduction of new products and portfolio adjustments. The goal of Product Change Management is to correctly market new products within boundaries and deadlines. HNS continuously strives to be leading in the set up and delivery of new product introductions for its customers.

- **Supply Chain Planning**
  
  Supply Chain Planning deals with the fit between demand from both domestic and export markets and the supply of raw materials, packaging materials, production and distribution capacity. The target is to schedule the production and logistics such that there is a healthy balance between customer satisfaction and profitability for the company. The department deals with the planning of three different product types: bottle one-way (bottles that are only used once; no return cycle), can and draught-keg and returnables (bottles, crates and (beer-tender) kegs, etc. Besides the production and logistics planning, also the brewing process and other associated processes are scheduled by this department.

- **Operations**
  
  The operational departments make sure that the planned operations are carried out according to the planning. A distinction is made between Inbound-, Domestic- and Export Logistics. Inbound Logistics is responsible for a correct amount of malt, bottles, cans, crates, labels, etc. in order to be able to brew, bottle and pack the products. The Domestic- and Export Logistics departments take care of the loading process of the trucks and containers before leaving to the customer.

- **Customer Service & Control**
  
  Customer Service & Control makes sure that the domestic customers receive the right products in the right amount and the right condition at the minimal operational costs. The distribution of roughly 225 customers is approximately as follows: supermarkets (54%), warehouse clubs (37%) and the hospitality industry (9%). This department maintains the communication with the customer.

- **Customer Service Export**
  
  Customer Service Export is the counterpart of Customer Service & Control and deals with the export customers. This department organizes and manages the worldwide transport of beer from the three Dutch breweries per container ship, truck, train or aircraft. This includes the required paper work (transport documentation and customs documents). As for the Customer Service & Control department, the communication with the customer is an important task for this department.

An overview of the organisational structure is shown in Appendix A.

CS&L is responsible for processing of pallets after they are delivered by the packaging department. Each year hundred thousands of pallets leave the brewery in Zoeterwoude. Section 2.3 provides some basic numbers on the pallet movements to sketch the complexity of the large-scale operations within the brewery.
2.3. Pallet Movements

In order to have an idea about the process under study it is important to know how the earlier described packaging lines relate to the container loading process. Also the number of shipments over the last couple of years may provide valuable insights that may later be used in the analyse phase.

Within HNS a distinction can be made between manual loading and loading by the Automatic Truck Loading System (ATLS). Manual loading can be further split up into regular loading and loading of loose-loaded containers. As explained earlier, these loose-loaded pallets are more complex to process and lead to a higher pallet supply due to different stacking patterns. The amount of loose-loaded pallets rose significantly over the past years. The pallet volume more than doubled since 2012 as can be seen in Figure 2.1.

![Figure 2.1: Outbound pallets export Zouterwoude Brewery](image)

Not only the amount of pallets shipped in loose-loaded containers increased, also the share with respect to all outbound pallets saw an increase. The share of loose-loaded pallets increased from 6% in 2012 to 14% in 2014. The share over the last 3 years can be seen in Figure 2.2.

![Figure 2.2: Outbound pallets share export Zouterwoude Brewery](image)

A major part of the loose-loaded shipments come from packaging lines 2 (21 and 22) and 7, but also part of the shipments come from packaging line 6. An overview of the pallet share for each line is shown in Figure 2.3. The data is retrieved from internal monitoring systems and represents the year 2014.
Section 2.4 will present the layout of the export loading area that is connected to line 2, 4 and 7.

2.4. Export Area CS&L Connected to Packaging Line 2, 4 and 7

In this section the physical lay-out of part (connection to packaging line 2, 4 and 7) of the export area at CS&L is presented. The floor plan is visualised in Figure 2.4.

The following elements can be observed:

1. Transfer car from packaging line 2 to cross-docks
2. Transfer car from packaging line 7 to cross-docks
3. Transfer car from packaging line 4 to cross-docks
4. Cross-dock for packaging line 2 (21 and 22)
5. Cross-dock for packaging line 7
6. Cross-dock for packaging line 4 (41 and 42)
7. Transfer car between cross-docks and (mechanical) loading stations
8. Mechanical loading station
9. Regular loading station
10. Mechanical loading station
11. Expelling track 1
12. Expelling track 2
13. Empty pallet stacker
14. Empty pallet conveyor
To have a better understanding on how these machines look in reality, part of the elements are shown in a on-site photo. The on-site photo can be seen in Figure 2.5.

The next section will describe the factors related to the elements included in the system under study.
2.5. Process Related Factors

The loading process is dependent on many factors. In order to be able to determine the focus area of the data collection and analysis it is necessary to identify these factors. These factors are determined by looking at the general process description as shown in Figure 2.7 and consequently indicating the elements that form the boundaries and boundary conditions for a smooth process.

- **Arrival of pallets**
  Before the pallets are ready for shipment, they are being processed by the palletiser, foil and labelling machine. This is defined as the boundary of the loading system. This is where the pallets enter the 'system'. The arrival of pallets is dependent on the performance of the packaging line, the planning and the product type (as mentioned earlier: loose-loaded shipments require more pallets for the same amount of boxes).

- **Cross-dock buffer**
  Each packaging line has its own dedicated buffer (although line 7 has two buffers; 6 and 7). The capacity of these buffers determines how many pallets can be produced before the production comes to a standstill. These buffers are designed to absorb potential failures during the loading process. Each buffer has a capacity of 42 pallets. The buffers for line 2, 4 and 7 are not connected to each other, hence buffer space is not exchangeable.

- **Machine capacity**
  Each machine (transfer cars and loading stations) has a maximum output (capacity). This capacity tells how many pallets each of these machines can process in one hour. This capacity may also be indicated as the speed of the machine within the chain. This capacity is dependent on machine limitations, but also on external factors (chance of damage at higher speeds).

- **Loading capacity**
  The loading process is to a large extend executed by manual operations. Therefore, next to the capacity of the machines, there is the capacity of the personnel (loading capacity). This loading capacity is dependent on the deployment of staff, the performance of the staff and the availability of the staff. Breaks and accidents for example limit the availability of the operators. Also sharing of resources may be a limiting factor; in case of a breakdown operators may be required on a different place as well.

- **Arrival of containers**
  Since there is a flow of pallets moving into the system, there also must be a flow of pallets leaving the system. These pallets leave the system by container. It is important that these containers are available at all times (if the pallets are ready for shipment). How fast the entire process is, if the containers are not available, all efforts are lost. This last link in the logistical chain is very critical.

- **Warehouse Management System**
  The WMS is the key chain within the loading process. The system is aware of all pallets entering and leaving the system. The WMS provides the 'orders' for each machine. These orders are based on input from either the pallets entering the system (arrival from the production) or from operators / warehouse coordinators that activate a particular shipment. These operators and warehouse coordinators may intervene the system at all times.

- **Availability of machines**
  Machines may break down or require maintenance. During these down times, machines are not able to operate according to their capacity. This is an important factor considering the loading process throughput. Especially the planned downtimes can be accounted for on beforehand by matching the buffer space with the downtime either by limiting the inflow or by freeing up buffer space just before the maintenance.
• Warehouse occupation
Some shipments are being produced hours / days (depending on the planning) prior to the moment of loading. These pallets need to be stored in the warehouse. Limited capacity may lead to extra time and delays in the loading process.

• Availability of docks
Related to the arrival of containers is the availability of docks such that the containers can be docked. There is a fixed amount of docks, however problems with the automatic truck loading system (ATLS) may decrease the amount of docks available for the system under study.

The process related factors as described above are summarised in Figure 2.6.

Figure 2.6: Process related factors loading process

The factors as mentioned in this section cannot be isolated. These factors are related to each other through planning and control. Also some factors limit the (usability of) others. A limited loading capacity due to limited availability of staff, leads to a higher occupation of the cross-dock buffer, limits the flow through the machines (transfer cars and loading stations) and decreases the arrival of containers (lower system output). Also, an unexpected high arrival rate of pallets leads to capacity constraints (e.g. not enough operators available for the load). The factors are subject to proper planning and control.

The next section will provide a better understanding of the process around the loading of containers.
2.6. Process Description

This section will describe the entire process around loading of containers, taking into account the process scope regarding packaging line 2, 4 and 7. The system boundary is taken at the input of pallets to the cross-docks. The process steps outside this boundary will be described briefly to provide some insights in the system inputs. The process continues until the product is placed in a container. The process can be described as follows:

- Products to be shipped are filled in the filling process.
- The filled products are then packed into boxes.
- The boxes containing the products are then stacked onto pallets.
- The finished goods (already packed on pallets) are transported from the palletisers (packaging department) to the wrapping machine and subsequently to the labelling machine.
- The wrapped and labelled pallets are moved via transfer cars towards the cross-docks (#1, #2 and #3 in Figure 2.4).
- After the items reach the end of the cross-docks (#4, #5 and #6), the pallets are picked up by a pallet transfer car (#7).
- The transfer car moves the pallets from the cross-docks to the loading stations (#8, #9 or #10). Loading station #8 and #10 are used for both mechanical and regular loading, whereas loading station #9 is only used for regular loading. If a pallet is directly fed to the mechanical loading station, the pallet moves over the conveyor towards the pallet removal plateau.
- The operator or system may also decide to remove the pallets from the system by means of the expelling track (#11 or #12), after which the pallets can be stored in the warehouse.
- At the mechanical loading station, an operator uses the forklift to remove the pallet from underneath the stacked boxes. The removed pallets are automatically stacked (#13). The stacked pallets (per 10 pieces) are moved over the conveyor (#14), such that a forklift operator can manually remove them.
- After the pallet is removed, the forklift operator places (pushes-off) the finished product in a container that is docked to the warehouse.

Note: the process description described the process of loading loose-loaded pallets. For regular pallets these steps are simplified, since the pallet does not have to be removed from the load before being placed in a container.

Figure 2.7 shows the above described steps schematically. The system under study (boundary) is marked grey.

The processes within the focus area can also be visualised using a IDEF0 diagram, providing for each separate activity the inputs, outputs, control and mechanism (Knowledge Based Systems Inc., 2015). The IDEF can be seen in Figure 2.8.
Now it is clear how the organisation is structured, which departments are involved and how the process around pallet movements is organised. The next chapter will provide a methodology on how to tackle the problem symptoms as described in Section 1.1.
This chapter will provide the tools and techniques that are being used throughout this research. In order to do the research within a proper framework and find related techniques for each step, a research framework is provided in Section 3.1. Throughout the framework the Theory of Constraints will be used. This theory is discussed in Section 3.2.

3.1. Research Framework
This research will be structured according to the DMAIC (Define, Measure, Analyse, Improve and Control) methodology as retrieved from the Six Sigma doctrine (De Feo & Barnard, 2003). DMAIC is a process improvement framework and can be used to structure a project. Besides DMAIC, there is another project structure method: DMADV (Define, Measure, Analyse, Design and Verify). The first one is purely related to improving existing processes, whereas the second one focuses on new processes (De Feo & Barnard, 2003). Since HEINEKEN Nederland Supply has a strong preference for a solution that requires minimum changes to the existing process, DMAIC is chosen to be the most suitable method.

3.1.1. Define
During the define phase the problem is being identified. The define phase of is already treated as problem statement in Chapter 1. The problem owners (actors) are discussed in Chapter 2.

3.1.2. Measure
During the measure phase data is collected. The data is retrieved from processes related to the problem symptoms. The collected data is processed such that it can be analysed later during the analyse phase. On-site measurements will be performed, interviews will be taken and database selections will be made.

By taking interviews with the employees that are daily involved in the loading process, a clear picture of the situation is obtained. Gill, Stewart, Treasure, and Chadwick (2008) describe the purpose of research interviews as to explore the views, experiences, beliefs and/or motivations of individuals on specific subjects. Qualitative methods (e.g. interviews) are believed to provide a ‘deeper’ understanding of social phenomena than would be obtained from purely quantitative methods, such as data analyses (Silverman, 2013). Interviews are therefore appropriate when little is already known about the study phenomenon or where detailed insights are required from individual participants. They are also particularly appropriate for exploring sensitive topics, where participants may not want to talk about such issues in a group environment (Gill et al., 2008).

In order to collect valuable interview answers and get full cooperation it is important that before an interview takes place, respondents are informed about the study details and given assurance about ethical principles, such as anonymity and confidentiality (Pope & Mays, 2013). To be able to analyse the roots of the spill-back problem one needs to know first if the employee is aware of the problem. It is also important to put the answers in perspective by obtaining more information about the specific
responsibility of the employees that are being interviewed. One of the two principles that are sug-
ggested by Stewart and Shamdasani (2014) regarding focusing groups is that questions should move
from general to more specific questions.

Based on this theory the following interview questions are generated:

- What is your specific task within the process of loading of (loose-loaded) containers?
- What is your experience within this loading process?
- Are you aware of the spill-back problem during this loading process?
- Can you point out the most important cause of this problem?
- Are there any other causes you can think of?
- Can you illustrate an example of a moment the problem was present?
- Where / by who is the most hassle experienced?
- How / by who is the problem in general solved?
- Is the provided solution a good solution? Are there other solution you can think of?

3.1.3. Analyse

During the analyse phase the collected data from the measure phase is analysed. These analyses have
one particular goal: finding the root-cause of the problem. At this stage the problem symptoms are
already described, however the roots of the problem are not known yet. Mobley (2015) described
a few commonly used main problem solving techniques that can be used to identify (and solve) the
underlying problem:

- Plan, Do, Check and Act (PDAC)
- Simplified Failure Modes and Effects Analysis (SFMEA)
- 5-Why Analysis
- Ishikawa Diagram

The first two techniques provide a broader framework for problem solving in general. The PDAC method
forms the basis for the two Six Sigma project methods described above. The SFMEA method uses the
RPN number (Severance * Occurrence * Detection) to prioritise problems (Mobley, 2015). The latter
two can be used to find the roots of the problem. The 5-Why analysis repeatedly asks the ‘why’-
question to dig into the problem (Bulsuk, 2009). The Ishikawa Diagram (or: Fish-bone Diagram) by
Ishikawa (1976) is a causal diagram used to find to causes of a problem. The causes are generally
grouped into categories like: people, methods, machines, materials, measurements and environment.

Next to the Ishikawa Diagram there are six other analysis methods that together form the seven ba-
sic tools for quality improvement (Montgomery, 2007). These tools include: the check sheet, control
chart, histogram, Pareto chart, scatter diagram and flow chart. Some of the analysis methods may be
used throughout the DMAIC framework. A Pareto Chart can be used to find the causes that contribute
most to the problem (Juran, 1962).

The process under study is subject to many variables, therefore an Excel model will be designed
to model the current system behaviour. This model will help in finding physical bottlenecks within
the logistical chain. This model compares the capacities of each link in the chain. Using graphical
representations ‘weak’ chains are found quickly.
3.1.4. Improve
During the *improve* phase the process is improved by focusing on the problem causes that were found during the *analyse* phase. As mentioned earlier, a model will be designed to find potential bottlenecks. The solution directions will follow from the analyses. The solutions can vary from changes in the ‘Planning’ as shown in Figure 1.2 (either by altering policies or hardware) or by looking for solution to possible problems in the ‘Realisation’.

3.1.5. Control
During the *control* phase, the improvements are being implemented in practise. The improved processes, or new infrastructure is monitored and data is collected. These measurements can be used to verify that the solutions are effective and that they are functioning as supposed. This phase will not be part of this research. The research will conclude with the steps as described in Subsection 3.1.4.

The entire project framework and the corresponding tools are visualised schematically in Figure 3.1.

![Project Framework](image_url)

*Figure 3.1: Project Framework*

The process under study is a logistical process that is subject to several sub-processes that may operate sub-optimal with respect to the up- and downstream processes. For this reason, throughout the phases as presented in the project framework (Figure 3.1) the Theory of Constraints will be used. The theory is briefly described in Section 3.2.
3.2. Theory of Constraints

A well respected problem solving / process improvement method is the Theory of Constraints (E. M. Goldratt, 1997). The Theory of Constraints (TOC) is a management paradigm that views any manageable system as being limited in achieving more of its goals by a very small number of constraints. This particular paradigm is developed by Eliyahu Goldratt. The theory states that every process has at least one constraint, which limits the system capacity. The constraint (or: bottleneck) is often easily resolved by means of small improvements. These improvements on the bottleneck may lead to large improvements to the entire process. Goldratt states that a lost hour on the bottleneck is a lost hour for the system. Improving on lost hours on non-bottlenecks is a waste of resources.

Measures
According to (Vorne, 2015), organisations can be measured and monitored by means of only three basic measures. These measures are:

1. Throughput: the rate at which the system generates money through sales
2. Inventory: the money that the system has invested in purchasing things which it intends to sell
3. Operational expense: the money that the system spends in order to turn inventory into throughput

Focusing Steps
To identify and eliminate (or work with) the constraint the following five steps need to be followed:

1. Identify the system’s constraint
2. Decide how to exploit the system's constraint
3. Subordinate everything else to the above decision
4. Elevate the system’s constraint
5. If in the previous steps a constraint has been broken, go back to step 1.

These five focusing steps focus on continuous improvement to the organisation’s constraint(s). Eliyahu refers to these steps as a 'Process of ongoing improvement'.

Chase (2001) described an approach to identify the bottleneck / system’s constraint. These steps can be formulated as follows:

- Visualise (by means of a flowchart) the process as a series of steps. These steps represent an interaction a human or machine (use of resources).
- Calculate for each step the theoretical capacity. Relate all these capacities to the first step in the process (percentages).
- Compare the percentages from the previous step. The highest value is theoretically the current bottleneck in the manufacturing process.
- Check above calculations by observation. Talk to operators and other related personnel to see if the bottleneck does exist in practice.
- Repeat this process until entire process is running below full capacity.
3.2. Theory of Constraints

Constraints
A constraint is anything that prevents the system from achieving its goal. There are many ways in which constraints may show up, however according to Goldratt there is always one and maximum a few per process. These constraints can be either internal or external. There is an internal constraint if the demand (of the market) is higher that the supply by the system. These internal constraints need to be tackled using the five focusing steps as described earlier. An external constraint means that the system is able to supply more that the (market) demand. Internal constraints may be grouped into three categories:

1. Equipment: the way equipment is used limits the overall system capacity
2. People: the way people perform (skills) their jobs limits the overall system capacity
3. Policy: the way things are done (due to written or unwritten policies) limits the overall system capacity

Theory of Constraints Applied
As discussed in Section 1.1, the filling machines are supposed to act as bottlenecks. These machines have a fixed maximum speed at which the quality of the final product is guaranteed. It seems that the bottleneck is moved to another stage within the production process, causing the filling machine to shut down as stated in the Problem Statement. This new bottleneck needs to be identified and removed by applying the Focusing Steps described earlier in this Section. A visual representation of a constraint is shown in Figure 3.2.

Figure 3.2: Visual representation of a constraint (E. Goldratt & Cox, 1992)

This chapter provided a framework and tools for the analysis of the system. The research will be structured according to the DMAIC methodology. Since the system is in general limited in achieving its goals, throughout the research the Theory of Constraints will be applied. Chapter 4 will focus on the measure phase of the DMAIC framework.
Process Analysis and Data Collection

This chapter will provide a detailed process analysis and presents the data collection process (the measure phase within the DMAIC method) required to identify the system’s bottleneck. It will therefore answer the second sub-question:

*What data need to be analysed in order to find potential bottlenecks?*

The process analysis is carried out by analysing the system using various process flowcharts in Section 4.1. The data collection process is provided in Section 4.2.

### 4.1. Process Analysis

This section will discuss the processes related to the loading process as a whole (which was introduced in Section 2.6). The detailed flowcharts that will be presented in this section are the result of on-site observations. In total, three processes will be looked at. For these processes the related steps, but more important the related decisions made during or after these steps are discussed. After analysis one is able to identify the potential ‘Policy’ and ‘People’ constraints, as discussed in Section 3.2.

![Process Transfer Car to Cross Docks Flowchart](image)

*Figure 4.1: Detailed flowchart representing the process of the transfer cars between the packaging lines and the cross-docks*
The first flowchart visualises the process the transfer car goes through when moving a pallet from the packaging lines towards the cross-docks. This is a process in which there are only two major conditions: enough buffer space and the availability of pallets. The flowchart can be seen in Figure 4.1.

The transfer car receives orders from the internal Warehouse Management System (further referred to as: WMS). The transfer car is triggered when the finished pallets move past a sensor that is located just after the labelling machine. As long as the sensor is not triggered, the transfer car is idle. Once triggered, the transfer car loads a pallet and moves to the cross-docks. On its way to the cross-docks the pallet is rotated by 90 degrees in order to be able to load the pallets later on. Once arrived at the cross-docks, the transfer car checks in the WMS if the destination cross-dock is fully occupied or not. If this is not the case, the pallet is unloaded. If the dedicated cross-dock is fully occupied, the transfer car will return to idle again until the last pallet moves past a sensor such that is buffer space again. The process may be intervened by the arrival of a forklift truck. Sensors in the floor detects the forklift and the transfer car waits before departure.

The second flowchart visualises the process of moving a pallet from the cross-docks (or buffers) towards to loading stations or expelling tracks (warehouse). The flowchart can be seen in Figure 4.2.

The transfer car receives orders from the WMS and processes these orders. If no order is available, the transfer car moves to a dedicated ‘rest’ position (between cross-docks 6 and 7) after 30 seconds of idleness. As will be explained later, orders need to be activated manually by the forklift operators. If a loading is activated, the transfer car moves to the destination cross-dock. After proper alignment of the transfer car with the cross-dock, the motor will start running, such that the chain starts moving and loads the pallets onto the plateau. After the pallets are properly positioned on the transfer car (this is measured using sensors), the transfer car moves to its destination point. The position of the transfer car is constantly measured using laser sensors (each position has a predefined coordinate). Again after proper alignment (this time with the loading station or expelling track), the motor again starts running and unloads the pallets (again controlled by a sensor checking the position of the pallets). If the next order is supposed to be delivered to the same destination as the current order, the transfer car waits until the pallets are moved past another sensor, such that room for the upcoming pallets is guaranteed. However, if the next order has a different destination, the transfer car moves to the cross-dock dedicated to the new order (if available).
The third flowchart visualises the process of moving a pallet from the loading stations or expelling tracks towards the docks or warehouse. The process is dependent on the availability of a correct container and the availability of a pallet to be loaded. The process is ongoing until a container is full. A full container needs to be finished properly (adding of air bag and closing the order in WMS) before moving on to the next container. The flowchart of this process can be seen in Figure 4.3.

The arrival of pallets on the cross-docks determines the request for a container via WMS. Each packaging line has a certain speed. This speed determines at what point in time a container is requested, such that the container is available at the dock on time for loading. If a container is not on time at the dock, the operator checks if the container already left the container terminal. If this is the case it may take up to 20 minutes before the container arrives. If the container did not depart yet, or is not available at all, the complete shipment gets the destination ‘warehouse’ and is transported via the transfer car to one of the expelling tracks.

The forklift operator is obligated to inspect the container and check if the container corresponds to the order to be loaded. If a container does not comply, the container is send back to the container terminal and a new container is immediately requested. If a container complies, the operator activates the order in WMS. The operator starts loading the pallets immediately if the first pallet arrives (and is properly positioned) on the loading station. The operator drives back and forth between the container and the loading station until the last pallet is put in the container. The bar-code of each pallet is scanned, such that the movement is registered in WMS. Consequently, in case of loose-loaded containers, the operator places an air bag between the front row pallets (in order to prevent damage during transport). The operator finishes the order in WMS and is ready for a new loading.
4.2. Data Collection
This section will provide more details on the data sources that give more insight in the current process. This data will be used later as input for the analysis. The measurements will mainly focus on technical machine capacities, such that technical shortcomings may be indicated or excluded as possible factors causing the problem in the analyse phase. The scope is further elaborated in Subsection 4.2.1. This section continues with the collection of pallet movements (Subsection 4.2.2), machine status reports (Subsection 4.2.3), internal incident registrations (Subsection 4.2.4) and concludes with on-site interviews (Subsection 4.2.5).

4.2.1. Measurement Scope
As mentioned earlier, a previous internal research measured the performance of the ‘current’ situation. Since the elements under study may have been changed or configured differently. As mentioned in Section 1.1, the symptoms are related to spill-back on the buffer lines just before the mechanical loading stations. Therefore it can be concluded that elements (machines) upstream of the connections to the buffer lines are not directly causing the symptoms of spill-back caused by CS&L. The data collection phase will therefore focus on the elements starting from the transfer cars in the process flowchart (shown in Figure 2.7). Also the interviews are carried out among personnel that is responsible for the above mentioned phases within the process.

The process under study is subject to different arrival patterns of finished goods towards the buffer lines. There are different production lines, different product types and different pallet dimensions. Performing on-site measurements requires many experiment repetitions in order to obtain measurements that are a valuable input for the analyse phase. At HNS every movement in the logistical process (starting from the labelling machines) is registered. These movements are processed into QlikView. QlikView consolidates data from multiple data sources into a single view BI tool (QlikTech International AB, 2015). This tool includes data that could otherwise have been retrieved by means of data measurements. Subsection 4.2.2 will present the data from QlikView concerning the process under study.

4.2.2. Registered Pallet Movements
Within the logistical process under study, three type of pallet movements are monitored within QlikView:

(A) Pallet movements from the packaging lines (labelling machines) towards the cross-docks
(B) Pallet movements from the cross-docks towards the loading stations or warehouse
(C) Pallet movements from the loading stations towards the containers (docks)

Figure 4.4: Monitored pallet movements in QlikView
4.2. Data Collection

Figure 4.4 shows the areas that are covered by the measurements in QlikView. The areas are related to the three movement types (A, B and C). The cross-docks and warehouse are indicated with red and grey, respectively. Area C only consists of manual (human) operations, potentially leading to random errors in the measurements. The data is exported to Microsoft Excel in order to be able to perform analyses in the analyse phase. QlikView includes the data of all production lines and buffers (also the ones outside the scope of this research). A selection is made to include the production lines attached to the cross-docks (these are: 21, 22, 7, 41 and 42). Only the pallets that are transported to the cross-docks are selected (pallets may be directly moved from the production line to the warehouse). The three measurement types each have their own Microsoft Excel file containing around 450,000 records (pallets). The most relevant columns included are: ‘Calender week’, ‘Shift’, ‘Date’, ‘Time’, ‘Movement from’, ‘Movement to’ and ‘Material description’.

Since the research is related to the pallet movements that are loose-loaded, another column is added indicating whether the pallet is loose-loaded or not (‘Yes’ or ‘No’). This is done by selecting the material descriptions that include ‘lo’. In order to be able to perform analysis on an hour-to-hour basis, two columns added containing: (1) the date and the hour of time (DD-MM-YYYY HH) and (2) the date and the half hour of time (DD-MM-YYYY HH x), where x is equal to 1 or 2 (indicating the first or second half hour). By doing so the data be grouped per half hour as well. This smaller time-step may potentially lead to more accurate data concerning the maximum machine / process capacities since a longer time period may level out periodic peaks. The effect of these different time groups will be evaluated later on.

The second data set (B) includes the ‘Movement to’ locations as presented in Table 4.1. This overview provides more insight in the meaning of each location. An example of part of the data collection is shown in Appendix C.

Table 4.1: ‘Movement to’ locations for dataset (B) explained

<table>
<thead>
<tr>
<th>Movement to</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Expelling track for warehouse storage</td>
</tr>
<tr>
<td>B</td>
<td>Expelling track for warehouse storage</td>
</tr>
<tr>
<td>M2</td>
<td>Regular loading station</td>
</tr>
<tr>
<td>M3, M4, M5</td>
<td>Pick-up point loading station 1, M3 for regular loading, M4 and M5 for loose-loaded</td>
</tr>
<tr>
<td>M8, M9, M10</td>
<td>Pick-up point loading station 2, M9 for regular loading, M8 and M10 for loose-loaded</td>
</tr>
</tbody>
</table>

4.2.3. Machine Status Reports

Within Heineken Nederland Supply all machines at the packaging lines and in the warehouse are monitored. Each machine can have several status: ‘Volloop’ (blocking), ‘Leegloop’ (starvation), ‘Storing’ (breakdown) or ‘Productiestop’ (production stop). These status are monitored continuously for each machine. The data can be visualised graphically with coloured bars or can be exported as raw data showing the amount of minutes a specific machine is in ‘Volloop’ status. An example of a (graphical) machine status report is shown in Figure 4.5.

The raw data is first pre-analysed to find ‘relevant’ data. Relevant data in this context is data that may be used for further analysis to find root-causes of the problem under study. Line 41 and 42 hardly show spill-back on the production lines, so the focus is on the remaining cross-dock-attached packaging lines; 21, 22 and 7. The data entries represent the downtime durations per shift (early: 6.00, late: 14.00 and night: 22.00). Both for line 2 (21 and 22) and line 7 a selection of 100 entries is made from the shifts that have the longest duration of downtime. Consequently the entries (shifts) are selected that are included in both lists. This selection provides a list of 29 shifts that have long downtime durations for both production lines. In order to be able to link the downtime to the production of a specific batch (loose-loaded pallets), the produced products on line 2 and 7 are mentioned in the data file as well.
Figure 4.5: Example of a Machine Status Report

The graphical representations of these shifts are now collected as well from the MES. The machine status reports may be used during the analyse phase to find possible causes to these downtimes. From the status reports it can be seen if the machines (or buffers) prior to the labelling machine of a particular packaging line showed downtime as well. The last links in the chain are the loading stations. If downtime is measured here, the cause cannot be further traced back from this data.

4.2.4. Internal Incident Registration

Since July 2014 CS&L started with the development of a database containing daily issues that are reported by the packaging department (issues related to CS&L), warehouse coordinators, team managers and other operational staff. The purpose of this database is to find the most occurring problems in order to find the cause of frequent problems, unwanted spendings or wastes of time. CS&L uses this information to solve frequently occurring process disturbances. Unfortunately the entries in this database are not yet properly categorised, making it impossible to make a selection of the problems related to spill-back on packaging line 21, 22, 7, 41 and 42.

The problems are sorted by searching for keywords such as the production line numbers, spill-back, loading, docks and containers. After the selection was made based on the manual keywords, a manual selection was made from the remaining items. In total 169 items were identified to be relevant to the research. The final result of this data collection is a raw set of problem descriptions related to the loading process of the pallets arriving from the cross-docks attached to the production lines delivering pallets for loose-loaded containers. The data collection can be found in Appendix D.

4.2.5. Interviews

Based on the interview questions as stated in Subsection 3.1.2 four people are interviewed. These people are responsible for the process of managing the export warehouse and loading the pallets in the containers. These interviewees mentioned the high arrival rate of pallets (which especially holds for loose-loaded orders) as the main problem cause. Several disturbances (e.g. errors, availability of containers) are mentioned that consequently lead to the observed spill-back of pallets. The results of the interviews are presented in Appendix E and will further be evaluated in Section 5.6.

This chapter provided the main ingredients for further analysis. The detailed process descriptions, data from the registered pallet movements, the Machine Status Reports, the internal incident registration and the interviews will be used for analysis in Chapter 5.
In this chapter the results from Chapter 4 will be analysed. Sub-question three and four will be answered during this analysis:

*What are the theoretical capacities within the loading process?*

*What are the causes of the spill-back from the warehouse to the packaging lines?*

Section 5.1 provides a starting point for the analysis. Whereas the first section will purely look at the influence of the related factors and process flowcharts (as discussed in Section 2.5), the remaining part of this chapter focuses on the analysis of the collected data. Section 5.3 analyses the pallet movements and provides more insight into the bottlenecks. An analysis of the machine status report is provided in Section 5.4. Section 5.5 includes a brief analysis of the internal incident registration database. The interviews are analysed in Section 5.6. This chapter concludes with a brief conclusion in Section 5.7.

### 5.1. Analysis of Process Related Factors

In this section the process related factors as described in Section 2.5 are analysed. For each of the factors the mismatches with either the planning or desired situation are discussed (see Figure 1.2).

- **Arrival of pallets**
  
  The arrival of pallets can be estimated from a predefined planning. Based on this planning, staff is deployed by the CS&L department. Based on on-site inspections this planning does not always show the true output from the packaging line (input for the system under study). Production may be ahead of schedule, leading to unexpected system input. This unanticipated extra system input in too large for the planned capacity, such that the pallets cannot be processed in time and causing an overflow on the buffers. The realisation does not match the planning in this case.

- **Cross-dock buffer**
  
  The cross-dock buffer is split up into six different buffers. As mentioned earlier, these buffers are connected to a dedicated packaging line. By doing so, it is easier to keep track of the pallets and consequently less complex to activate an order (to be loaded). The problem however of this approach is that the buffer space cannot be used in an optimal way. Say, packaging line 21 is not producing any products and that containers for packaging line 7 have an enormous delay causing buffer 6 and 7 to fill up. Once both cross-dock are completely full, spill-back on the packaging line leads to a standstill of packaging line 7, while effectively there is still buffer space available on the other buffers. The planning does not match the desired situation in this case.

- **Machine capacity**
  
  The machine capacity will be analysed in Section 5.3. Mismatches between the required capacity and the practical capacity can be either mismatches between the planning and the desired situation (bad design) or mismatches between the realisation and planning (e.g. unplanned downtime).
• **Loading capacity**
  The loading capacity is subject to a high level of variance. It was found that depending on the operator, the loading time for one pallet varies between 30 and 60 seconds (or: 60-120 pallets per hour). During moments that the pallet input is limited, two operators at a rate of 60 pallets per hour may perfectly be able to deal with the system input. However, if all packaging lines are producing at full capacity, 120 pallets (60 times 2 operators) per hour may be far from sufficient. By inspection it was found that operators are not available at all times. Breaks and shift relays are causing temporary capacity drops that lead to an increased amount of pallets on the buffers. Also the current planning model does not account for peaks (hourly) in the production. The model lacks granularity (the higher the level of granularity, the more detailed a model is). These factors are largely related to the mismatch between a desired situation and planning.

• **Arrival of containers**
  The arrival of containers is dependent on multiple factors. First of all a container needs to be ‘reserved’ prior to the moment of production (reservation for a particular day). On the day of production, the container is called off automatically when pallet X of N (dependent on the product and packaging line speed) enters the cross-dock. It may occur that the ordered container is not available on-time, the container may be delayed or a wrong container is delivered. These scenarios can cause major problems for the entire logistical chain. The pallets for the particular shipment cannot be loaded (directly) causing the cross-dock(s) to fill up. Problems regarding to the container availability can be either mismatches between the realisation and planning, however if there was a lack of communication between the packaging department and CS&L the planning did not match the desired situation.

• **Warehouse Management System**
  The Warehouse Management system was introduced to monitor and better align movements and processes. The WMS is open to inputs from operators and warehouse coordinators. This ‘openness’ may lead to unwanted / suboptimal decisions that influence the process negatively. These unwanted decisions can be related to wrong container requests (from the warehouse coordinator) or pallet movements to a wrong location / loading station. These are all mismatches between the realisation and planning.

• **Availability of machines**
  The machine availability at CS&L is a very crucial factor. Most machines following after the packaging line, do not have any redundancy built in. Especially the transfer car between the cross-docks and the loading station may cause a downtime for three separate packaging lines. Unexpected downtimes are caused by a gap between the realisation and planning.

• **Warehouse occupation**
  The warehouse is the only place where pallets can be moved to in case one is not able to load a container. This space can be used as buffer space such that a potential process disturbance (e.g. missing container) does not lead to downtime on the packaging lines. Insufficient space itself does not influence the process, however it may fail as a backup. Unexpected disturbances are (by definition) not fully accounted for, hence a lack of warehouse capacity in this case can be indicated as a mismatch between the realisation and planning.

• **Availability of docks**
  In order to be able to load containers, docks need to be available for these containers. In case the ATLS is not able to operate, multiple docks cannot be used for loading. The load that was supposed to be loaded via these docks now has to be loaded on different docks. By using these different docks, there are less docks available for loading from packaging line 2 and 7. This causes the hourly amount of containers to drop leading to ‘gaps’ in the loading operation, and consequently to spill-back on the cross-docks (and packaging lines). Dock availability is expected to be self-evident, hence problems can be categorised as mismatches between the realisation and planning.

The next section will provide an analysis of flowcharts representing the system’s processes.
5.2. Analysis of Process Flowcharts

The flowchart in Figure 4.1 shows the process of the transfer cars between the packaging lines and cross-docks. From the flowchart it can be seen that the transfer car waits at the cross-docks in case there is no buffer space available, which leads to a reduced capacity. The transfer car could have moved to the packaging line already, such that waiting time is converted in operational time. Also, the fact that the transfer car intersects with crossing forklifts, overall capacity is reduced.

The second flowchart, Figure 4.2, shows the process of the transfer car between the cross-docks and loading stations. The flowchart does not show any obvious points for improvement, however the transfer car shall always receive pick-up orders (on time) to ensure maximum output. It was noted that in case the transfer car only has pick-up orders for one particular loading station, the transfer car waits (at the loading station) until the loading station has enough room for one or two new pallets, instead the transfer car could have moved to the cross-docks already.

The last, and most extensive flowchart was seen in Figure 4.3. This flowchart shows the loading process from an operator perspective. The first thing that is noticed is that the operators have major influence on the process itself. An operator makes the decision which container to load and from which loading station. These decisions are not only prone to errors, they also lead to reduced performance of the system. The operator loses valuable time during the period an order needs to be activated and pallets need to be moved to the loading station. One should consider moving responsibilities to the WMS or warehouse coordinator.

The small changes as discussed above are only effective if, and only if, these steps within the process are none bottlenecks as described by the Theory of Constraints in Section 3.2. The capacities within the process need to be analysed first. This analysis will be carried out in the next section.

5.3. Registered Pallet Movements and Process Capacities

As mentioned earlier, this section will provide an analysis on the data collection including the pallet movements at the Zoeterwoude brewery of HEINEKEN Nederland Supply. This data will be used to find the hourly pallets movements in year 2014. These numbers can be used to get a grip on the practical capacities of the machines / processes. These capacities will be compared with the (maximum) output of the packaging lines, such that a potential bottleneck can be found (as explained by the Theory of Constraints in Section 3.2). Since the data is split in three areas, also the analysis will be carried out separately. Before looking at the registered pallet movements, the theoretical pallet input is discussed in Subsection 5.3.1. The pallet movements by the different production stages are compared using the capacity curve (V-Graph) in Subsection 5.3.7.

5.3.1. Theoretical Pallet Input

Before looking at the registered pallet movements at CS&L, one should look at the theoretical pallet movements originating from the packaging lines. The number of pallets that are being produced per hour is dependent on the speed of the filling machines and the number of bottles per box and pallet. The speed of the filling machines is retrieved from the Supply Chain Planning department (Section 2.2). The following speeds are obtained for packaging line 21, 22, 7, 41 and 42, respectively: 40,000, 27,750, 80,000, 2700 and 2700 bottles (or kegs) per hour. It seems however that the average planning speeds do not exactly match the true speed settings for the different packaging lines. This in particular hold for packaging line 21, 22 and 7. The speeds vary per line, but also per bottle type. Also there is a difference in speed between the filling machine and the packaging machine. To have a better understanding of the current packaging line output, an average value for these packaging lines is calculated for week 21 to 25 from 2015. The maximum and average values are retrieved from the corresponding packaging departments and are summarised in Table 5.1.

There are eleven different bottle types being produced on line 21, 22 and 7. Line 41 and 42 produce 5L kegs (minimum 60 kegs per pallet). The products produced on line 21, 22 and 7 including the %-occurrence in 2014 the number of bottles per box, the average number of boxes per pallet and the lowest number of boxes per pallet (leading to the largest number of pallets for the same amount of
bottles) are visualised in Appendix F. The occurrence is shown to determine the probability of certain product combinations to occur. The largest pallet output is obtained when using the following product / pallet configurations: 250K2 LO for line 21, 650K2 LO for line 22 and 330K2 LO & 330SOL LO for line 7. This data will be used to determine the scenarios in the theoretical Bottleneck Analysis in Subsection 5.3.7.

Table 5.1: Filling and packaging speeds for line 21, 22 and 7 [bottles / hour]. Averages are from week 20-24 2015

<table>
<thead>
<tr>
<th>Line</th>
<th>Bottle</th>
<th>Maximum Filling</th>
<th>Average Filling</th>
<th>Maximum Packaging</th>
<th>Average Packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>207HK</td>
<td>42000</td>
<td>30866</td>
<td>48960</td>
<td>32049</td>
</tr>
<tr>
<td></td>
<td>250K2</td>
<td>42000</td>
<td>27417</td>
<td>48960</td>
<td>28095</td>
</tr>
<tr>
<td></td>
<td>250K2 LO</td>
<td>42000</td>
<td>27417</td>
<td>48960</td>
<td>28095</td>
</tr>
<tr>
<td></td>
<td>330K2</td>
<td>40000</td>
<td>26854</td>
<td>48960</td>
<td>27886</td>
</tr>
<tr>
<td></td>
<td>330K2 LO</td>
<td>40000</td>
<td>26854</td>
<td>48960</td>
<td>27886</td>
</tr>
<tr>
<td></td>
<td>355K2</td>
<td>40000</td>
<td>27891</td>
<td>48960</td>
<td>29269</td>
</tr>
<tr>
<td></td>
<td>355K2 LO</td>
<td>40000</td>
<td>27891</td>
<td>48960</td>
<td>29269</td>
</tr>
<tr>
<td>22</td>
<td>330K2</td>
<td>40000</td>
<td>23835</td>
<td>48960</td>
<td>24335</td>
</tr>
<tr>
<td></td>
<td>330K2 LO</td>
<td>40000</td>
<td>23835</td>
<td>48960</td>
<td>24335</td>
</tr>
<tr>
<td></td>
<td>355K2</td>
<td>39000</td>
<td>26168</td>
<td>48960</td>
<td>26331</td>
</tr>
<tr>
<td></td>
<td>355K2 LO</td>
<td>39000</td>
<td>26168</td>
<td>48960</td>
<td>26331</td>
</tr>
<tr>
<td></td>
<td>650K2</td>
<td>23000</td>
<td>15607</td>
<td>24480</td>
<td>15931</td>
</tr>
<tr>
<td></td>
<td>650K2 LO</td>
<td>23000</td>
<td>15607</td>
<td>24480</td>
<td>15931</td>
</tr>
<tr>
<td>7</td>
<td>330K2</td>
<td>80000</td>
<td>58146</td>
<td>99360</td>
<td>59855</td>
</tr>
<tr>
<td></td>
<td>330K2 LO</td>
<td>80000</td>
<td>58146</td>
<td>99360</td>
<td>59855</td>
</tr>
<tr>
<td></td>
<td>355K2</td>
<td>80000</td>
<td>50036</td>
<td>99360</td>
<td>50241</td>
</tr>
<tr>
<td></td>
<td>355K2 LO</td>
<td>80000</td>
<td>50036</td>
<td>99360</td>
<td>50241</td>
</tr>
<tr>
<td></td>
<td>330SOL</td>
<td>80000</td>
<td>46580</td>
<td>99360</td>
<td>48040</td>
</tr>
<tr>
<td></td>
<td>330SOL LO</td>
<td>80000</td>
<td>46580</td>
<td>99360</td>
<td>48040</td>
</tr>
</tbody>
</table>

Table 2.1 already demonstrated the filling capacities of the packaging lines (based on an OPI of 100%). By using these capacities, the number of bottles per box and the number of boxes per pallet, the filling capacity can be converted to pallets per hour. This is done using the following multiplication:

\[
\text{Pallets per hour} = \text{Filling capacity} \times \text{Bottles per box} \times \text{Boxes per pallet} \tag{5.1}
\]

Using this ‘worst’ product mix and using the minimum number of boxes per pallets, an pallet input of 185 pallets per hour is received from the filling machine (35, 38, 67, 23 and 23 pallets per hour for packaging line 21, 22, 7, 41 and 42, respectively). The packaging machine is capable of producing even more pallets per hour. Taking into account the maximum packaging speeds for packaging line 21, 22 and 7, a maximum hourly pallet output of 209 is found. Of course, this output will only be seen for a very short time after a temporary breakdown of this packaging machine (over-capacity enables the machine to clear the buffer). This concept is visualised in Figure 5.1. It is assumed that these time periods are short enough that it hardly influences the pallet output. Using the average filling capacity from week 20-24 2015, a pallet output of 133 pallets per hour is found.
5.3. Registered Pallet Movements and Process Capacities

![Diagram showing production of filling and packaging machines with different production capacities.

Figure 5.1: Concept of buffer recovery

The maximum output of the packaging lines taking into account the ‘worst’ product mix and using the minimum number of boxes per pallet is 185 pallets per hour. The average output from week 20-24 2015 was 133 pallets per hour. After the products are produced, packed, placed on pallets and provided with foil and labels, the pallets are transported towards the cross-docks of CS&L. These movements are discussed in the next subsection.

5.3.2. Pallet Movements from the Packaging Lines

The first dataset that is analysed includes the pallet movements from the labelling machine (packaging line) to the cross-docks. These movements are an important indicator for the maximum number of pallets per hour that were offered to the cross-docks under study. Figure 5.2 shows the demand pattern for the year 2014. This demand pattern demonstrates that the production operates according to (seasonal) peaks.

![Graph showing demand pattern for CS&L 2014.

Figure 5.2: Demand pattern 2014 for CS&L (per day)

More importantly is to see the number of pallet movement during one-hour time blocks. These pallet movements can easily be compared later on with the hourly pallet movements of other system components. These movements are sorted on descending order, such that it is easy to find the maximum hourly movements. From Figure 5.3 it can be observed that the maximum number of pallet movements during one hour was equal to 154. As mentioned earlier, the data can also be based on 30 minute time steps. The maximum movements found is now equal to 81 (or: 162 pallets per hour). The difference (8 pallets/hour) is due to the fact that peaks are levelled off by averaging the number of pallets in one hour. The fact that this number (162 pallets per hour) is smaller than the 185 pallets per hour, which was found in Subsection 5.3.1, means that the packaging lines never saw the maximum pallet output scenario appearing in 2014 for all packaging lines at the same time or there might be a limiting factor between the filling machine and input of the cross-docks causing the limit of 162 pallets per hour.
A higher (marginally) throughput is however found for smaller time-steps, however smaller time-steps may lead to increased inaccuracies since the number of pallets are always integers. The latter phenomena is clearly visible in Figure 5.4. This graph shows for each minute the pallet count corrected to hours (each entry is multiplied with 60). Due to the small number of pallets movements during one minute intervals, manual inputs (multiple pallets at a time) and the timing of the measurements (including nearly finished movements), this interval leads to highly biased data (movements of 1260 pallets/hour are found). The remaining two data sets will use for this reason the 30-minute interval data.

The transfer cars that actually move these pallets from the packaging line (labelling machine to be precise) are each capable of processing one pallet every 52.6 seconds (average of 25 pallet movements). This means that for all three lines a maximum output per transfer car of 3600/52.6=68.4 pallets per hour is found.

The transfer cars from the packaging lines towards the cross-docks each has a capacity of a little more than 68 pallets per hour. The pallet movement from the cross-docks are discussed in the next subsection.

5.3.3. Pallet Movements from the Cross-Docks
The second data set includes the movements from the cross-docks towards the loading stations or warehouse. This data is directly related with the capacity of the accompanying transfer car. In order to have an idea about the possible routes followed by the transfer car, the share of all movements is visualised in Table 5.2. These route choices may be used later on during the improve phase. There are nine destination locations possible, however both loose-loading stations have three loading points each, as shown in Table 4.1. These route choices lead to reduced performance of the transfer car. It has been found that the the top 500 half-hour entries in terms of pallet movements show a significantly (t-test: paired two sample for means) higher amount (share) of pallet movements towards location 'B' (21 versus 19 percent), potentially due lower travel distances during these movements.
5.3. Registered Pallet Movements and Process Capacities

Table 5.2: Share of movements from the cross-docks to the loading stations

<table>
<thead>
<tr>
<th>Movements</th>
<th>To</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUFFER06</td>
<td>A 5%</td>
<td>B 14%</td>
</tr>
<tr>
<td>BUFFER07</td>
<td>A 10%</td>
<td>B 12%</td>
</tr>
<tr>
<td>BUFFER21</td>
<td>A 10%</td>
<td>B 12%</td>
</tr>
<tr>
<td>BUFFER22</td>
<td>A 5%</td>
<td>B 9%</td>
</tr>
<tr>
<td>BUFFER41</td>
<td>A 19%</td>
<td>B 55%</td>
</tr>
<tr>
<td>BUFFER42</td>
<td>A 20%</td>
<td>B 61%</td>
</tr>
</tbody>
</table>

To find the maximum number of pallets transported by the transfer car, a top-10 of half-hour entries is made. This list is visualised in Table 5.3 and shows the distribution of pallets on these specific time-steps. It can be concluded that the maximum number of pallets transported by the transfer car in 2014 is equal to 186 (93 times 2) pallets per hour. During this time frame (13-03-2014 09.30-10.00) a large portion of pallets is moved to M2. 25-11-2014 16.30-17.00 provides a better representation of the transfer car capacity (movements are evenly distributed between expelling track A and both (loose-loaded) loading station). 87 pallets are transported during this time frame, hence leading to a capacity of 174 pallets per hour.

Table 5.3: Top-10 half-hour entries concerning pallets movements from the cross-docks

<table>
<thead>
<tr>
<th>Date</th>
<th>Movements</th>
<th>To</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 03 2014 09 2</td>
<td>A 0</td>
<td>B 13</td>
<td>M10 24</td>
</tr>
<tr>
<td>01 04 2014 12 2</td>
<td>A 16</td>
<td>B 65</td>
<td>M10 0</td>
</tr>
<tr>
<td>11 11 2014 20 1</td>
<td>A 3</td>
<td>B 30</td>
<td>M10 0</td>
</tr>
<tr>
<td>10 06 2014 11 1</td>
<td>A 0</td>
<td>B 20</td>
<td>M10 0</td>
</tr>
<tr>
<td>20 05 2014 12 2</td>
<td>A 0</td>
<td>B 38</td>
<td>M10 0</td>
</tr>
<tr>
<td>25 11 2014 16 2</td>
<td>A 28</td>
<td>B 0</td>
<td>M10 2</td>
</tr>
<tr>
<td>23 10 2014 21 2</td>
<td>A 20</td>
<td>B 24</td>
<td>M10 0</td>
</tr>
<tr>
<td>03 04 2014 09 1</td>
<td>A 0</td>
<td>B 6</td>
<td>M10 1</td>
</tr>
<tr>
<td>03 04 2014 23 1</td>
<td>A 9</td>
<td>B 0</td>
<td>M10 28</td>
</tr>
<tr>
<td>16 03 2014 16 2</td>
<td>A 4</td>
<td>B 15</td>
<td>M10 28</td>
</tr>
<tr>
<td>24 07 2014 23 1</td>
<td>A 14</td>
<td>B 20</td>
<td>M10 4</td>
</tr>
</tbody>
</table>

The capacity of the transfer car between the cross-docks and the loading stations / expelling tracks is 174 pallets per hour. The next subsection will elaborate on the pallet movements on the loading stations.

5.3.4. Pallet Movements on Loading Stations

After the transfer car moves the pallets from the cross-docks to the loading stations, the loading stations need to move the pallets to a predefined location at which the pallets can be picked up. The capacity of these loading stations is dependent on the type of loading and specific machine. As mentioned earlier the mechanical loading stations are able to process both loose-loaded and regular pallet loadings. Earlier research (van der Heide, 2013) showed that the capacities for loading station 1 and 2 (see Figure 2.4) are 109 and 108 pallets per hour for loose-loaded pallets. All three loading stations are able to process 140 pallets per hour for regular loading. These numbers are confirmed by on-site measurements. Loading is in general done with a maximum of two forklift operators leading to 8 possible loading scenarios, each with its own capacity (see Table 5.4).
From Table 5.4 it can be seen that the most critical scenario is that both operators are loading loose-loaded pallets from loading station 1 and 2. A maximum capacity of 217 pallets per hour is found for this particular scenario.

The capacity of the loading stations is dependent on the type of loading. In case that both operators are loading loose-loaded pallets, the capacity is in total 217 pallets per hour.

5.3.5. Pallet Movements from Loading Stations and Expelling Tracks

After the pallets arrive on the loading stations, the pallets need to be transported towards the docks. These movements are performed by means of manual operations using forklifts (the entire procedure is described in Section 2.6). First the isolated measurements from the loading stations are investigated. Like for the previous dataset a top-10 of half-hour entries is made for the measurements. Based on Table 5.5 it can be concluded that the maximum number of pallets transported from the loading stations in 2014 is equal to 182 (91 times 2) pallets per hour. The maximum number of pallets removed from both the loading stations and the expelling tracks equals 106 (or: 212 pallets per hour). It is assumed that packaging line 41 and 42 are moved to the expelling tracks and therefore not being loaded (from Table 5.2 it follows that for packaging line 41 and 42, respectively 74% and 81% of the pallets are being expelled).

There is however something wrong with the 'capacity' that is found using the real loading data. To find the maximum number of pallets an operator is able to move in a certain time span requires that the supply of pallets is infinite (or: at least just as high as the maximum output of the operator). Since the maximum output of the transfer car was found to be 174 pallets per hour, this may indeed be a constraint for the loading operation and may cause starvation of the loading station.

To find the 'real' theoretical capacity of the forklift operators one should know how long it takes an operator to load a single pallet. This number can be used to calculate the total number of pallets this particular operator can process in one hour. Again, this number is dependent on the type of loading,
but also on the distance between the loading station and the dock. The latter is not taken into account as an average loading time will be calculated. However, a distinction between regular and loose-loaded loading will be made. Again the same loading scenarios as in the previous subsection will be used. With an average pallet loading time of 30 and 45 seconds for regular and loose-loaded loading respectively, the following hourly pallet movements are found (see Table 5.6). The average loading times were calculated earlier and were confirmed by on-site measurements. The fastest operator is able to load a loose-loaded pallet every 32 seconds (112-113 pallets per hour per operator).

Table 5.6: Loading scenarios including corresponding overall forklift operator loading capacity

<table>
<thead>
<tr>
<th>S / LO</th>
<th>Loading station</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>LO</td>
<td>LO</td>
<td>LO</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>LO</td>
<td>S</td>
<td>-</td>
<td>LO</td>
<td>S</td>
<td>-</td>
<td>LO</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>S</td>
<td>-</td>
<td>-</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Pallets/h</td>
<td>160</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>240</td>
<td>240</td>
<td>200</td>
<td>240</td>
<td></td>
</tr>
</tbody>
</table>

The capacity of the loading process is dependent on the forklift operators and the type of load. Two very fast operators are able to process 225 loose-loaded pallets per hour. The average operators will process around 160 pallets per hour.

5.3.6. Dock Availability

As discussed earlier, the dock availability is an important factor within the system. If all process stages operate perfectly in harmony, but there are no containers to ship the finished goods, the system is unable to operate (for a very long time). Container requests have a lead time of about 45 minutes between the request and the arrival. Packaging line 21 and 22 both have 2 docks available (4 in total), whereas packaging line 7 has 3 docks available. For packaging line 21 and 22 this leads to 2 containers every 45 minutes (or: 2.66 containers per hour). For packaging line 7 this leads to 3 containers every 45 minutes (or: 4 containers per hour). Using the most critical load (24 pallets per container), a capacity of 64 pallets per hour is found for both packaging line 21 and 22 and a capacity of 96 pallets per hour is found for packaging line 7. It should be noted that these capacities can only be reached if the arrival is perfectly aligned with the loading operations.

A perfectly aligned arrival of containers leads to a dock availability / capacity of 128 pallets per hour for packaging line 2 and a capacity of 96 pallets per hour for packaging line 7.

5.3.7. Bottleneck Analysis

Now that the capacities of the stages between the filling machine and the loading process are known, one can compare these capacities with respect to the filling capacity. The filling capacity was indicated to be most critical, therefore the capacity is set as base capacity (100%). The machine capacities of the stages following after the filling machine are weighted calculated with respect to this number (a capacity of 120% indicates that the particular machine can process 20% more items than the filling machine).

The tactical planning department of HNS uses an average OPI for each packaging line, however in practise, the filling machine is able to operate (although for a limited amount of time) on 100% OPI. For the capacity calculation different scenarios are analysed. The most critical product / pallet configurations were mentioned in Subsection 5.3.1 for each packaging line. Also the minimum (most critical) amount of boxes per pallet was presented in Appendix F.

Figure 5.5 shows the capacity curve of the ‘worst’ case scenario (as presented earlier: 185 pallets per hour input). From the graph it can be concluded that that capacity of the transfer car from packaging line 2 (21 and 22) towards the cross-docks does not have sufficient capacity (below the filling machine capacity) to keep up during critical conditions. Also the transfer car between the cross-docks and the
loading stations is not able to keep up with the supply of the packaging lines. These system processes are called ‘constraints’ or ‘bottlenecks’.

Figure 5.5: Capacity curve (worst case scenario)

It may be argued how realistic the worst case scenario is. It was already found (Subsection 5.3.2 that the maximum system input was 162 pallets per hour in 2014. It was at that point unclear if this limit was caused by a capacity constraint or if the theoretical maximum was never achieved in practice. From Figure 5.5 it was concluded that the transfer car between packaging line 2 and the cross-docks was insufficient. However, with a maximum output of over 68 pallets per hour for all three packaging lines, it can be concluded that the input maximum input was not limited to the system constraints. Also the output of packaging line 2 was never (in 2014) above 60 pallets per hour, questioning the presence of the transfer car (from packaging line 2 to the cross-docks) as a constraint.

In Table 5.1 it was already demonstrated that the average packaging line output for week 20-24 2015 was significantly lower (on average) than the theoretical maximum output of the packaging line. The capacity curve for this system input is shown in Figure 5.6. The system input is now reduced to 133 pallets per hour and may be more representative for daily operations. It can be seen that no bottleneck with respect to the filling machine is found, however the transfer car between the cross-docks and loading stations (131%) is still a limiting factor for quick removal of pallets from the cross-docks.

Figure 5.6: Capacity curve (average week 20-24 2015)

In case of a maximum pallet input, the capacity of the transfer car of packaging line 2 is insufficient. The capacity of the transfer car just after the cross-docks is insufficient. For an average pallet input (week 20-24) the capacities within the logistical process are sufficient.
5.3.8. Conclusion
From the registered pallet movements analysis it can be concluded that the capacity of the transfer car from packaging line 21 and 22 is insufficient to handle with both packaging lines during production of the 250K2 LO and 650K2 LO at the same time. The capacity of the transfer car between the cross-docks and loading stations is insufficient to cope with the pallet flow from packaging line 21, 22, 7, 41 and 42 at the same time. As said, it may be questioned if these ‘constraints’ have caused the problem, since the maximum number of pallet movements from last year (2014) were lower and within the capacities of the processes. It can therefore be concluded that these system constraints were not causing spill-back during normal operation last year. Since a continuous improvement process is going on to increase the packaging line OPI and with increasing amount of orders, this constraint will definitely lead to larger problems in the future.

The next section presents the analysis of the machine status reports as discussed in Section 4.2.3.

5.4. Machine Status Reports
Subsection 4.2.3 described the collection of machine status reports including data on spill-back. It was found that 29 shift (in the year 2014) were having major downtime durations caused by CS&L. After inspection of the machine status reports, 4 reports show no signs of these particular downtimes, indicating that the data was incorrect.

From the remaining 25 reports, 6 reports show signs of spill-back towards the labelling machines, while the loading stations are emptying their buffer. Further analysis indicated that the transfer car from the buffers to the loading stations was operating at a high rate (above 160 pallets per hour). From this it can be concluded that these particular delays were caused by a limited capacity of the transfer car between the cross-docks and the loading stations.

The remaining reports do not provide enough evidence to base conclusions on. Spill-back on one of the loading stations may indicate a too high workload, but may also be triggered due to damage of a box. Spill-back on the cross-docks may be caused by a broken transfer car, but may also be triggered if no order is activate on the loading stations (due to container availability). The uncertainty that is demonstrated here leads to the conclusion that the remaining 19 reports are not suitable for a proper root-cause analysis.

Based on MES it can be determined to what extend the spill-back at CS&L caused the packaging lines lines to stop in the middle of a production run. Based on the results of 2014, the OPI losses for the packaging lines are shown in Table 5.7. Part of the OPI losses are caused by external stops. These external stops are partly influenced by problems with the supply of materials or the removal of pallets from the packaging lines. This research deals with the losses caused by the latter category.
### Analysis

<table>
<thead>
<tr>
<th>Packaging Line</th>
<th>Losses category</th>
<th>OPI loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging Line 21</td>
<td>External stops</td>
<td>0.3% OPI</td>
</tr>
<tr>
<td>- No supply of materials / removal of pallets</td>
<td>0.2% OPI</td>
<td></td>
</tr>
<tr>
<td>- No removal of pallets</td>
<td>0.2% OPI</td>
<td></td>
</tr>
<tr>
<td>Packaging Line 22</td>
<td>External stops</td>
<td>0.2% OPI</td>
</tr>
<tr>
<td>- No supply of materials / removal of pallets</td>
<td>0.1% OPI</td>
<td></td>
</tr>
<tr>
<td>- No removal of pallets</td>
<td>0.1% OPI</td>
<td></td>
</tr>
<tr>
<td>Packaging Line 7</td>
<td>External stops</td>
<td>1.9% OPI</td>
</tr>
<tr>
<td>- No supply of materials / removal of pallets</td>
<td>1.5% OPI</td>
<td></td>
</tr>
<tr>
<td>- No removal of pallets</td>
<td>1.3% OPI</td>
<td></td>
</tr>
<tr>
<td>Packaging Line 41</td>
<td>External stops</td>
<td>1.5% OPI</td>
</tr>
<tr>
<td>- No supply of materials / removal of pallets</td>
<td>1.1% OPI</td>
<td></td>
</tr>
<tr>
<td>- No removal of pallets</td>
<td>1.0% OPI</td>
<td></td>
</tr>
<tr>
<td>Packaging Line 42</td>
<td>External stops</td>
<td>1.8% OPI</td>
</tr>
<tr>
<td>- No supply of materials / removal of pallets</td>
<td>1.2% OPI</td>
<td></td>
</tr>
<tr>
<td>- No removal of pallets</td>
<td>1.0% OPI</td>
<td></td>
</tr>
</tbody>
</table>

6 out of 25 machine status reports with the highest downtime periods show evidence of a limited capacity (bottleneck) of the transfer car after the cross-docks.

#### 5.5. Internal Incident Registration

Subsection 4.2.4 described the collection of data from an internal incident registration database. A selection of the data was already made, however still a rough collection of incidents remained. In order to be able to analyse the data, all 169 entries are manually given a category. These categories are used to group the 169 divergent descriptions. From the categorised data a Pareto chart was made, such that the main (registered) problem causes can be indicated. The Pareto chart is visualised in Figure 5.7.

![Figure 5.7: Pareto chart of an internal incident registration database at HNS](image-url)
From the Pareto chart it can be seen that the container availability represents a large share of the registered incidents (46%). The container can either be unavailable due to problems during the transport over sea / rivers, the container can be unavailable due to a delayed transport from the terminal to the brewery or the container may be unavailable due to improper planning and communication between the brewery and the container terminal (the Alphereum of van Uden in Alphen aan den Rijn).

According to A. van Baal (Contract Manager at HEINEKEN Nederland Supply) improper planning and communication between the brewery and the container terminal is the result of not following the internal weekly planning (personal communication, July 15, 2015). CS&L discusses the container requests with the terminal approximately one week ahead. van Uden makes sure that the containers are at the container terminal 48 hours before the container is supposed to be transported to the brewery. It happens that if the packaging department is ahead of planning it starts working on orders for the next day. The planning between CS&L and the container terminal does not account for this, leading to ‘missing’ containers for various shipments. Also late departures from the container terminal are among the causes regarding the availability of containers. Currently there are no penalties into place regarding late deliveries.

Also technical problems with the docks, availability of inspection and workload can be seen as major problems from this analysis.

The internal incident registration database indicates the container availability as a major (46% of all problems) problem within the loading process. Other problems are technical problems to the docks, absence of inspectors and a high workload.

5.6. Interviews

The final step in the data analysis is to analyse the answers to the interview questions as stated in Subsection 4.2.5. The answers of the interviews match to a large extent. The interviews were conducted among three experienced people working as a warehouse coordinator and forklift drivers. All interviewees were aware of the spill-back problem especially during loading of loose-loaded containers.

There are multiple problem causes pointed out. The warehouse coordinator indicates that the increased amount of loose-loaded orders have led to a limited dock availability (due to the higher pallet arrival rate, more container positions are required to preserve a continuous flow). All three forklift drivers mentioned the limited speed / capacity of the transfer car between the cross-docks and the loading stations as the main problem cause. The first forklift driver indicates that waiting for the transfer car in the past led to an increase in loading time of five minutes per container. The forklift drivers all mention the correlation with packaging line 41 and 42 during the problem occurrence. Most of the time the problem occurs when both packaging line 21/22 and 7 are producing loose-loaded pallets, while 41 and 42 are producing as well. Other causes that were mentioned are the availability of containers, human errors, un-experienced forklift drivers, broken pallets and limited warehouse capacity.

The interviewees indicate that most hassle is experienced at the CS&L department due to higher workloads and warehouse utilisation, but also mainly at the packaging department due to downtime. The problem is in general solved by reducing the flow towards the cross-docks by eliminating pallets earlier on in the process from packaging line 41 and 42. Or by expelling entire orders (in case of a delayed / cancelled container).

The provided solutions do not satisfy the interviewees, however these solutions are in practise (within the current situation / within their control) the only solution. A better solution that is mentioned is to have a faster transfer car and better training instructions for the forklift drivers.

The main problem cause indicated by the interviewees is the limited capacity of the transfer car. Other main causes are the limited availability of containers, human errors and un-experienced forklift drivers.
5.7. Conclusion

This chapter provided the analyses required to identify the underlying problem of the spill-back on the packaging lines due to CS&L. The registered pallet movements have demonstrated that the pallet movements are showing a peak pattern. These peaks in supply can in theory be too high to be processed by the transfer car(s) as seen in Section 5.3.7. There is a mismatch between the planning and desired situation.

The next analysis indicated that at least 6 out of 25 machine status reports showed spill-back due the transfer car from the cross-docks towards the loading stations. The maximum number of movements that were found are lower than the maximum throughput, indicating that the transfer car may not be able to fully utilise the capacity due to suboptimal logistical control. There is a mismatch between the planning and desired situation.

The internal incident registration database showed a different main problem cause: container availability. The container availability is currently being addressed in a work group together with the container terminal. This problem is indicated as a mismatch between the realisation and the planning.

Finally the interviews revealed valuable information on the problem cause. The speed / capacity of the transfer car was indicated to be the main cause for the spill-back towards the packaging lines. Most problems occurred when three (21/22 and 7) packaging lines were producing loose-loaded containers, while 41 and 42 were producing as well (towards the expelling tracks). The root causes that were found by means of the analyses in this chapter are summarised in Figure 5.8. The general categories as stated by Ishikawa (1976) are slightly altered to better represent the situation.

![Ishikawa diagram of root causes found from analyses](image)

The problem and the problem causes that are discussed are part of the entire system called HEINEKEN. The problem does indirectly lead to consequences that are being felt all the way up in the company. A simplified overview of this will be provided by means of a causal loop diagram. Besides the Ishikawa diagram as shown earlier, the causal loop diagram (Greenland & Brumback, 2002) shows the relations between the various components in the system and visualises how the found problem causes are related to the problem itself, but also what the indicated problem eventually does to the system. These causes and potential improvements to these causes will be discussed in Chapter 6. The causal loop diagram can be seen in Figure 5.9.
5.7. Conclusion

Although theoretical pallet input numbers indicate the transfer cars as being constraints, analysis showed that the process capacities were sufficient for the maximum pallet input received in 2014. Hence, without disturbances, no spill-back should have occurred last year (which obviously was not the case). Somehow the interviewees still indicate the transfer car (between the loading stations and cross-docks) as a bottleneck. There is only one explanation for this phenomena: more is asked from the transfer car than supplied by the packaging lines. Now it makes sense that small disturbances (as mentioned by the interviewees) following each other up in a short period, are causing spill-back. The operators are simply not able to clear the cross-docks (buffer) in time, before a new disturbance arises. The transfer car lacks sufficient over-capacity to guarantee quick removal of pallets after a disturbance. In other words: under normal conditions, without disturbances, the system is able to process the amount of pallets received from the packaging lines at the current rate of arrival of pallets. However, as found during the bottleneck analysis, the packaging lines are in theory able to produce more pallets than the transfer car can process.

Figure 5.10 shows graphically what happens if the downtime causes more pallets to arrive than the amount of pallets that were removed in the period before the downtime. Gradually the buffer will become more occupied until the buffer reaches its limit, causing the packaging line to shut down.
A practical example of this phenomena occurred on the 30th of June 2015 (6 AM shift). The container terminal had problems in delivering the containers due to an accident with a barge. This led to multiple disturbances within the system’s processes. It was not immediately known which containers were affected. It was therefore not possible to anticipate on this fact. The result was that shipments were waiting on the cross-docks before being loaded (if a replacement container was available) or expelled to the warehouse. The buffer occupation was constantly close to 100%, leading to spill-back when another downtime period (small disturbance) was introduced. The Machine Status Report of this particular example can be seen in Figure 5.11.

The analyses in this chapter resulted in various root-causes to the initially stated problem. The causes were categorised in mismatches between the realisation and planning and between the planning and desired situation. Potential improvements to the problem causes will be discussed in Chapter 6.
In this chapter various potential improvements will be provided for the problem causes found during the analysis. This chapter will answer the final sub-question:

*What changes lead to increased system performance and reduced spill-back?*

Before being able to provide improvements regarding the problem statement, the analyses from Chapter 5 are used to define solution directions. The list of potential solutions are then narrowed down to a list of solutions to work with. These solution directions are discussed in Section 6.1. The provided solutions will be further elaborated on within the predefined situation framework. In particular, there were two type of problems indicated (retrieved from Figure 1.2):

1. Mismatch between the realisation and the planning
2. Mismatch between the planning and the desired situation

The first mismatch can either be solved by improving the realisation or by altering the planning to better match that particular realisation. Solutions to this mismatch are discussed in Section 6.2. The second mismatch can either be solved by making a planning that better fits the desired situation or it might be that a proper planning is not possible because of limitations in the process. This mismatch is discussed in Section 6.3. To eliminate the problem both mismatches need to be solved, hence the realisation shall be according to a planning that matches the desired situation.

### 6.1. Solution Directions

This section will discuss the solution directions towards the problem statement. These solutions are retrieved from the previous analyses (long-list), then narrowed down by looking at the solution requirements and boundary conditions. This section will work towards a short-list of potential improvements.

### 6.1.1. Identification of Solutions from the Analyses

In Chapter 5 the root-causes to the initially stated problem were discussed. It is not doable to deal with all these causes, however in terms of resources it would likely also be very inefficient to to so since in general 80% of the effects come from 20% of the causes (Koch, 2011). Now, move back to causal loop diagram in Figure 5.9. One either has to remove the arrows that lead to increased (+) spill-back of pallets on the cross-docks, or one has to look at the arrows that negatively (-) influence factors that reduce the spill-back. Also from the Ishikawa diagram in Figure 5.8 additional root-causes can be indicated. This subsection will work towards a long-list of possible solutions.

From the causal loop diagram, different factors can be indicated as positively influencing the increase of spill-back of pallets on the cross-docks. These factors are: 'Utilisation of transfer car’ and ‘Machine breakdowns'.
1. Utilisation of the transfer car

The higher the utilisation of the transfer car (between the cross-docks and the loading stations), the less capacity is remaining for incidents, hence the more spill-back of pallets on the cross-docks. The utilisation is positively influenced by the input from the packaging lines, which on itself is positively influenced by an increasing number of loose-loaded orders. The utilisation is negatively influenced by an increasing capacity of the transfer car. So, to lower the utilisation of the transfer car under normal conditions (no disturbances) there are two options: decrease the input from the packaging lines or increase the capacity of the transfer car.

2. Machine breakdowns

The more machine breakdowns, the less pallets are removed from the cross-docks, hence the more spill-back of pallets on the cross-docks. Machine breakdowns are negatively influenced by maintenance. Regular maintenance lead to less machine breakdowns, however increases the costs for the company (the company makes a trade-off here). On the other hand, human errors positively influence the machine breakdowns. These errors are negatively influenced by proper training and more managing responsibility of the warehouse coordinator. So, to lower the number of machine breakdowns there are two options: increase to amount of maintenance of machines critical for the loading process, provide proper training to the operational staff and increase the managing responsibility of the warehouse coordinator.

Besides the factors that positively influence (increase) the spill-back of pallets on the cross-docks, there are also some factors that negatively influence (decrease) the spill-back of pallets on the transfer car. These factors are: ‘Buffer size’, ‘Warehouse capacity’ and ‘Available containers’:

3. Buffer size

The buffer size (or: length of the cross-docks) determines the number of pallets that can be positioned on the cross-docks without spill-back from the cross-docks to the packaging lines. This buffer size negatively influences (decreases) the spill-back of pallets on the cross-docks, since more spare time is available after a disturbance. It should be noted that extra buffer capacity does not lead to a reduced number of pallets on the cross-docks. It does however in general lead to a reduced buffer occupation (%).

4. Warehouse capacity

The warehouse capacity was found to be one of the causes of spill-back. Warehouse capacity negatively influences (decreases) the spill-back of pallets on the cross-docks. This means that by increasing the warehouse capacity, the occurrences of spill-back of pallets on the cross-docks will be reduced.

5. Available containers

The more available containers, the more pallets can be taken from the cross-docks, hence less spill-back on the cross-docks will occur. The container availability is positively influenced by proper planning, proper communication and the availability of docks. So, to increase the number of available containers there are three options: improve the planning of containers, improve the communication with the container terminal and / or increase the number of available docks.

6. Loading capacity

The higher the loading capacity, the more pallets can be removed from the loading stations (given that the upstream capacities are equal or higher). The loading capacity is positively influenced by the communication with the packaging department and the granularity of the planning model. The planning model is then positively influenced by gaining insight in the peak pattern of the production and the differences between operators. So, by accounting for the peak pattern, the differences between operators and by improving the communication with the packaging department, the loading capacity may be increased.

The available solution directions are shown in Figure 6.1 using crosses (cut connection if possible) and arrows (increase factor if possible). Now by summarising the options following from the causal loop diagram and by taking the causes from the Ishikawa diagram in Figure 5.8, the following long-list can be made (the numbers correspond to the factors discussed above):
6.1. Solution Directions

- 1.1 Decrease the input from the packaging lines to the cross-docks
- 1.2 Increase the capacity of the transfer car
- 2.1 Increase the amount of maintenance to the critical machines
- 2.2 Provide more training to the operational staff
- 2.3 Increase the responsibility of the warehouse coordinator
- 3.0 Increase the usable buffer size / length of the cross-docks
- 4.0 Increase the capacity of the warehouse
- 5.1 Improve the planning of containers
- 5.2 Improve the communication with the container terminal
- 5.3 Increase the number of available docks
- 6.1 Account for peak pattern in planning model of staff
- 6.2 Account for differences between operators when planning
- 6.3 Improve the communication with the packaging department

Figure 6.1: Causal loop diagram with solution directions

The next subsection will discuss the requirements and boundary conditions regarding the solution directions as discussed in this subsection.
6.1.2. Solution Requirements and Boundary Conditions

In the previous section a long-list of possible solutions was presented. HEINEKEN Nederland Supply has set several requirements and boundary conditions regarding the solution and its implementation. The following requirements were set:

- The solution shall reduce the OPI losses due to no removal of pallets.
- The solution implementation shall not disturb the packaging process.
- The solution shall fit within the current infrastructure (no redesign of entire warehouse).
- The solution shall be implemented according to the safety guidelines.
- The solution shall fit within the culture of Heineken.
- The solution shall be manageable by team leaders / technical staff.
- The solution shall cost less than 400,000 euros.
- The solution shall not reduce the warehouse capacity by more than 5%.
- The solution shall not lead to idleness of operational staff.

These requirements shall be taken into account during the process of defining proper improvements. From the above requirements, it can be seen that the first requirement actually rephrases the main goal of this research. The second requirement is more challenging since another solution has to be designed besides the main solution to backup the production process.

A few of the above requirements narrow the scope of the solutions. Since the requested solution has to fit within the current infrastructure, increasing the warehouse capacity is not possible. One may decide to store pallets on a different (external) location, however since that does not directly provide additional space (pallets can not immediately be taken from the cross-docks and transported to the remote location) this potential improvement is not further taken into consideration. Also regarding the fit within the current infrastructure, it is not possible to increase the number of available docks. One might look into the possibility of restructuring the dock assignment method, such that more containers can be allocated to one dock. By doing so, the probability of not having an empty container in the right place on the right time, will decrease. Further research shall be done on this to investigate the effects and consequences of this improvement. This potential improvement will not be taken into account further on in this chapter.

Improving the planning of the containers is not part of this research. It is assumed that better communication (which is treated later on in this chapter) will for a large part lead to a better daily planning of the containers. Since the container planning is dependent on many other factors outside the responsibility of CS&L, this solution is not further taken into consideration.

The last requirement, that the solution shall not lead to idleness of operational staff, eliminates another solution. Solution direction 6.1 (accounting for peak pattern in planing model of staff) is focused on a better availability of operators during peak hours. Since there are three shifts on a day, it is not possible to add more granularity to the model and specifically plan for these 1-2 hour peaks. An employee is either deployed for the shift or the employee is not deployed for the shift. Deployment of operators is based on the total number of movements to be done during a shift.

In the next subsection the list of potential improvements is now modified to account for the elimination of some improvements following after this subsection. It shall be noted that solution direction 2.3 and 5.2 will be combined.

6.1.3. Short-List of Potential Improvements

After narrowing down the list of potential solutions by viewing them in the light of the requirements and boundary conditions, there are a few solutions left that will be further discussed in the remainder of this chapter. These solutions are split-up into the two mismatch categories as discussed earlier. The short-list of solutions is now as follows:
Potential improvements to the mismatch between the realisation and the planning

- Improve the communication with the container terminal
- Improve the communication with the packaging department
- Provide more training to the operational staff
- Increase the amount of maintenance to the critical machines
- Account for peak pattern in planning model of staff
- Account for differences between operators when planning

Potential improvements to the mismatch between the planning and the desired situation

- Decrease the input from the packaging lines to the cross-docks
- Increase the capacity of the transfer car
- Increase the usable buffer size / length of the cross-docks

In this section the outcomes of Chapter 5 were reviewed. Using the requirements and boundary conditions this resulted in a short-list of potential improvements that will be further discussed and assessed in the remainder of this chapter.

6.2. Mismatch Between Realisation and Planning

In this section the potential improvements and their feasibility are presented and assessed. This section focuses on the mismatch between the realisation and planning.

6.2.1. Improve the Communication with the Container Terminal

More responsibility shall be given to the warehouse coordinators, such that the daily communication between the Alpherium and the brewery is better aligned. Information about delayed containers can directly be used to coordinate the loading process and shift priorities, instead of noticing a missing container when an entire order is already positioned on the cross-docks.

A 'missing container' can also be caused by the trucking company. There are KPIs being used to monitor the on-time arrivals, however the consequences of not fulfilling the target are limited (to none) as mentioned by A. van Baal (personal communication, July 15, 2015). Weekly meetings are organised to talk about the issues during last weeks planning and the corresponding KPIs. The Alpherium has to make sure that a container can be delivered within 45 minutes after the request (under the condition that the container is available at the Alpherium). Strict rules and penalties shall be introduced, such that this factor can be eliminated. These penalties shall be two-sided, hence if the number of planned containers is higher than the amount of containers needed, a comparable penalty will follow, such that both parties try to optimise their planning and deployment of personnel and trucks.

As long as an accurate monitoring system is in place, external factors are taken into account and as long as both the trucking company and the brewery have comparable rules / regulations it is perfectly possible to have more strict rules regarding performance of the container trucking. The penalties shall be proportionally high with respect to the potential savings that can be made by not following the defined rules. Koploy (2011) indicates that a penalty only leads to a better supply chain operation if used systematically and effectively. He points out that penalties cannot effectively be used without incentives. One should use penalties to keep suppliers on track, but also incentives to encourage suppliers to strive for success, beyond what is expected. It will benefit both parties and help nurture a lasting relationship.

Based on the Internal Incident Registration database it is expected that 25% of the problems regarding the container availability can be prevented (the remaining 75% of the problems are due to delivery problems from the shipping companies to van Uden and are outside the scope of this research) by
improving the communication between the container terminal, making better appointments and by introducing penalties. This improvement requires no major investments besides some policy changes and additional daily (to-the-point) communication (status updates). Since it was found that 46% of the registered disturbances were caused by problems regarding the container availability, approximately 12% of the registered disturbances will be eliminated.

6.2.2. Improve the Communication with the Packaging Department
The internal communication between the packaging department and CS&L shall be improved. Before starting with a new order, it shall be checked if there is still a possibility to request a container in time, or if warehouse capacity is available to store the shipment. At the same time CS&L can anticipate on the extra movements that are related to the order. This extra communication leads to less frustrations from both the packaging department and CS&L as both departments know what is possible / what is coming. Although it may seems contradicting for the packaging department to adjust their operations to the capabilities of the warehouse (CS&L department), in the end less spill-back leads to less standstill of the packaging line.

The main obstacle for better communication with the packaging department is the fact that that each planning is already very limited by constraints. More constraints will leave very limited room for planning and may in the end lead to a planning that is far from optimal in terms of overall throughput, again according to (E. Goldratt & Cox, 1992) the bottleneck (the filling machine) shall always be prioritised. Other bottlenecks shall be eliminated.

For this solution it is not exactly known what the effect of implementation is on the overall system performance, and how it decreases the spill-back occurrences. Like for the first solution, this solution can be implemented at no cost. So it is worth to start up a pilot of one or two months, in which the effectiveness of this solution is tested and evaluated.

6.2.3. Provide More Training to the Operational Staff
One of the possibilities to avoid human errors is by providing extra training. Training make the operators better aware of the equipment they are dealing with, but more importantly, they become aware of the possible problems they might encounter and how to quickly and effectively solve them. Operators should also be better trained to work with the WMS. Not directly related to training, but a substitution solution for the above, is limiting the direct interaction of operators with the WMS. By making the warehouse coordinator responsible for the activation procedures of the shipments, it is less likely that pallets are ‘send’ to the wrong loading station or are loaded in the wrong container. The warehouse coordinator should have a better overview of the entire situation (e.g. buffer occupation and container arrivals), ensuring operational decisions that are better aligned with the planned situation.

It is expected that problems labelled with: ‘Work load’, ‘WMS’, ‘Human error’ and ‘Damage’ (following from the analysis in Section 5.5) can be linked to the solutions provided in this subsection. By counting the number of occurrences of these categories, it is found that 10% of the problems may be solved by the proposed solutions.

Providing better training is always a possibility and reduces the number of errors made. These errors can however not be eliminated entirely. Every human interaction is prone to errors as stated by Reason (1995). A research showed that an increase of 1 percentage point in the proportion of employees trained is associated with about a 0.6% increase in productivity (Dearden, Reed, & Van Reenen, 2006). Brum (2007) indicates that training leads to a higher employee commitment. The shift of responsibilities to the warehouse coordinators shall be further investigated. Warehouse coordinators already have many administration related tasks. CS&L is looking into the possibilities of taking away some of these tasks, such that more time is left for operational interventions.

6.2.4. Increase the Amount of Maintenance to the Critical Machines
It is assumed that disturbances from machine breakdowns are inevitable. These occurrences may be decreased by better alignment (and more maintenance), but there will always be multiple parties involved trying to reduce the costs to a minimum. Extra maintenance cost money and maintenance
outside of production hours (during the weekends) is even more expensive. Based on inspection and repair reports, the breakdowns of the machines downstream of the labelling machine are not leading to a significant drop in machine availability. Without introducing additional maintenance to the critical machine, one should focus on the timing of the maintenance and checks. Based on production planning it is possible to plan the maintenance just before the peak moments. By doing so the probability of downtime during these peaks is reduced. Since most pallet movements take place during these peak hours, the potential losses are minimised.

Maintenance is important for production operations and for continuous improvement. According to Langer et al. (2010), appropriate dispatching of the maintenance workforce to quickly respond to equipment failures and carry out preventive services can improve system productivity. The first-come-first-served policy is typically used in many manufacturing industries. It is shown by extensive simulation experiments that a priority-based dispatching policy (maintenance worker will service the high-priority machine (i.e. bottleneck machine) first when multiple service requests are received), based on the analysis of real-time data can lead to a greater improvement in system throughput compared with the first-come-first-served policy.

6.2.5. Remaining Solution Directions

There are two more solution directions. These improvements are more or less categorised as quick fixes and will not be discussed in detail. The remaining solution directions positively influence the loading capacity. The two improvements that are left are the following:

- Account for peak pattern in planning model of staff
  By taking into account the peak pattern in the production planning, one is better able to plan the staff (operators) and make sure that enough loading capacity is available.

- Account for differences between operators when planning
  As found during the analysis, the loading time per operator varies a lot. The operators shall be rated according to their performance. During planning one has more insight in the total loading capacity if the average loading time is known. This prevents that two operators with a high loading time are planned together and form a bottleneck in the logistical process.

In this section the improvements to the mismatch between the realisation and planning were discussed and assessed. The next section will cover the potential improvements to the second problem category: the mismatch between the planning and desired situation.

6.3. Mismatch Between Planning and the Desired Situation

In this section the potential improvements and their feasibility are presented and assessed. This section focuses on the mismatch between planning and the desired situation.

6.3.1. Decrease the Input from the Packaging Lines to the Cross-Docks

This solution is to ‘create’ over-capacity at the transfer car by reducing the flow towards it. This can for example be achieved by decreasing the speed of the filling machines. Another way to decrease the system input is to decrease / eliminate the input from packaging line 41 and 42 to the cross-docks and by removing the pallets at an earlier moment upstream of the cross-docks (especially when these pallets are not supposed to be directly loaded).

By decreasing the maximum pallet input to the cross-docks from (in theory) 185 to 139 (-46) pallets per hour, the transfer car is not a bottleneck any more. Also, more capacity is left to clear the buffers after a disturbance in the process. With respect to a maximum pallet input, the transfer car has an ‘over-capacity’ of 174 - 139 = 35 pallets per hour. Although this brings the transfer car to a capacity of 125% with respect to the output of the packaging lines, it still takes many hours before the buffers are recovered from a major disturbance. This solution alone is therefore not sufficient to entirely prevent the spill-back effects as shown in Figure 5.10.
Improvements

It is also possible to decrease the flow by limiting the bottle flow through packaging line. This will definitely solve problems experienced by CS&L. It is however very unlikely that this leads to end-to-end optimal solutions. By definition, from the Theory of Constraints (E. M. Goldratt, 1997), it is not possible that reducing the flow through the bottleneck (filling machine) leads to a solution towards ‘the goal’ (making money for the company). Still it is possible to limit the flow by eliminating the input from line 41 and 42 upstream of the cross-docks. This will increase the workload of the warehouse operators since hardly any buffer space is available after the packaging line. As long as these task fit within the daily job of the already available operators, this solution can only be benefited from. If it not possible to assign these tasks to already planned operators, the costs shall be weighted against the benefits.

Another option is to better align the production with the capabilities of the CS&L department. By doing so, one might decide to limit loose-loaded orders to a maximum of two lines at the same time. One could spread the orders more evenly, such that the peak pattern (Figure 5.2) will disappear. This will also ease the deployment of forklift operators, since the flow can be better predicted. However, according to the HEINEKEN Master Plan 2015-2020 is is expected that the loose-loaded orders will see an increase at the Zoeterwoude Brewery. This increase in inevitable since the demand for special beer types that are only being produced in Den Bosch is expected to grow significantly, leading to the decision to move loose-loaded orders from Den Bosch to Zoeterwoude.

6.3.2. Increase the Capacity of the Transfer Car

The capacity of the transfer car between the cross-docks and loading stations need to be increased such that it is not a bottleneck anymore with respect to the packaging lines, but also to loading stations and forklift operators. This seems contradicting to the Theory of Constraints, however since the cross-docks are in essence major buffers of pallets, the flow of pallets after a disturbance is infinite (pallets are waiting to be served). Subsection 5.3.5 showed that the maximum capacity of a forklift driver is approximately 112 loose-loaded pallets per hour. For two operators this gives a loading capacity of 224 pallets per hour. It was also found that the maximum capacity of the loading stations is 217 pallets per hour (see Subsection 5.3.4) for these loose-loaded pallets. So in theory, if the transfer car is able to process at least 217 pallets per hour, the output is maximised within the limits of the loading stations and operators. Taking into account that also packaging line 41 and 42 need to be served, the capacity shall be increased to 217 + 23 + 23 = 263 pallets per hour.

![Increased transfer car capacity and its up- and downstream processes](image)
From Figure 6.2 it can be seen that a capacity of 263 pallets per hour leads to an over capacity of 80 pallets per hour with respect to the maximum output of the packaging lines and their transfer cars. This ensures that the transfer car itself is never a bottleneck for the downstream process. The same effect is obtained when setting the capacity of the transfer car to 217 pallets per hour, while at the same time removing the pallets from line 41 and 42 locally (see previous solution).

**Practical solution**

One example of a possibility to increase the capacity is by adding an additional transfer car. This solution will decrease the loading flexibility with respect to the number of destinations for each packaging line destinations (loading stations). Due to limitations in the available space it is not possible any more to load pallets from packaging line 21 to the loading station and expelling track on the right. Also, the WMS will be more complex due to the new constraints that will be introduced. On the other hand, at the moment there is zero redundancy in the system when the current transfer car fails. With the introduction of a second transfer car, it always remains possible to serve (part of) the packaging lines in case of a breakdown or during maintenance. The proposed solution is visualised in Figure 6.3. According J. Wentink, the installation manager at HEINEKEN Nederland Supply (personal communication, August 27, 2015), the implementation of this solution is fairly simple as the transfer car can be manufactured on beforehand, before putting it in position. The new constraints and rules for the WMS can be prepared as well. He points out that the new software design may be challenging. Afterwards, it may take a few days, up to a week to test the solution and make the proper adjustments to the controllers of the transfer cars or WMS. During this period of downtime, the pallets need to be removed locally from the packaging lines. This may require extra forklift operators for the time being to ensure quick removal of pallets.

![Figure 6.3: Increase transfer car capacity: additional transfer car](image)

**Assessment of solution**

The investment in a replacement for the current transfer car can be best assessed by looking at the difference in time it takes to empty the cross-docks after a major breakdown that caused the individual buffers to reach its full capacity. It is assumed that cross-docks 41 and 42 remained operational, since they are in general not dependent on the loading station or the availability of containers. A MATLAB model has been created to visualise the pallet movements from the packaging lines, over the cross-docks, via the transfer car to the loading stations or expelling tracks. The model is a simplified representation of the reality, however it does provide a realistic view of the potential improvements that follow from the replacement for the current transfer car. The model is purely used for a rough estimation on the consequences of the replacement (improvement). The model assumptions, inputs and outputs, verification and validation and the MATLAB code of this model can be found in Appendix G.
To assess the solution, four scenarios are tested. Scenario 1 looks at the impact of a maximum pallet input from all production lines in the current situation. The result is shown in Figure 6.4. Scenario 2 uses the same parameters except that the solution (replacement to the current transfer car) is in place. The outcome is visualised in Figure 6.5. Scenario 3 and 4 follow the same reasoning, except that the input is now following from the average line output from week 20-24 2015 as used in Table 5.1. The model outputs of these scenarios are visualised in Figure 6.6 and Figure 6.7, respectively. The tested scenarios are summarised in Table 6.1.

Table 6.1: Model scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Input from packaging line [pallets / hour]</th>
<th>Capacity transfer car [pallets / hour]</th>
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From Figure 6.4 it can be seen (as already concluded in Subsection 5.3.7) that the output is not sufficient to keep up with the input from the packaging lines. There is even a small deficit with between the capacity and the input. The input is equal to 176.4 pallets per hour. This is somewhat lower than the theoretical maximum pallet input calculated in Subsection 5.3.1. The reason for this is that the pallet input from packaging line 21 and 22 is limited by the transfer car between these lines and the cross-docks.

In Table 5.7 the OPI losses per packaging line due to no removal of pallets were summarised. According to P. Hoondert it is expected that 80% of these losses can be eliminated by the implementation of a new transfer car (as proposed in this section) (personal communication, August 25, 2015). These OPI losses can be expressed in money. Within the brewery there is a savings list describing the costs involved for each packaging line for a loss of 1% OPI. These losses are mainly based on idle personnel and energy usage. These savings are indicated as non cash savings, since these losses do not directly
lead to less FTE (full-time employees) or less energy usage. These savings do only apply in case the packaging line operates under full capacity. The losses (per % OPI) for packaging line 2, 7, 41 and 42 are as follows: €28.825, €24.042, €8.277 and €8.277. As shown in Table 5.7 the losses from packaging line 2 (21 and 22) average to 0.15% OPI. For packaging line 7 an OPI loss of 1.3% was found and for packaging line 41 and 42 a loss of 1.0% OPI was registered. When multiplying these numbers with the savings and taking into account the 80% factor, the following potential savings are found:

- Packaging line 2: €3.460
- Packaging line 7: €25.000
- Packaging line 41: €6.620
- Packaging line 42: €6.620

These savings add up to €41.700. Again, these are non cash savings and only lead to cash savings if the same amount of products can be made in a shorter time, leading to the removal of a shift. Currently (starting beginning 2015), there are some packaging lines operating on full capacity. This led to the refuse of some orders (and thereby to losses of sales). According to T. van Ruitenbeek the impact of this is much larger than the OPI savings as discussed above (personal communication, August 12, 2015). At the moment (up to July 2015), the lost sales on packaging line 21 adds up to over €100.000. This adds up to 1.4% of the total yearly volume, hence only a fraction of these losses are compensated if the solution is implemented. For packaging line 7 a sales loss of almost €40.000 is found. This loss adds up to 0.2% of the total volume, therefore these losses can be completely compensated.

From Figure 6.5 it can be seen that an output capacity of 263 pallets per hour from the cross-docks is more than sufficient to keep up with the input from the production lines, while at the same time reducing the buffer occupation to zero for all lines in a little more than 2 hours and 45 minutes.
From Figure 6.6 it can be seen that the pallet input for Scenario 3 is equal to 133 pallets per hour (as mentioned in Subsection 5.3.1). Using the current transfer car capacity it takes almost 7 hours to clear the cross-docks. By replacing this transfer car by a solution that provides a capacity of 263 pallets per hour, the cross-docks can be emptied in just over 2 hours as shown in Figure 6.7.
6.3.3. Increase the Usable Buffer Size / Length of the Cross-Docks

One of the solutions is to increase the buffer size. By doing so, more space is available for the pallets to be positioned. This gives extra room to absorb the disturbances. The buffer space can either be increased by making the cross-docks longer or by using the available space more efficiently. Because of the requirement that the solution shall fit within the current infrastructure, it is not possible to increase the length of the cross-docks. On both sides of the cross-docks there is insufficient space to implement the additional length.

The effective buffer space per packaging line can be increased by using the available space in a more efficient way. Say, packaging line 41 and 42 are not producing any pallets, the cross-docks will remain unoccupied. This available buffer space can be used for the pallets of the other (remaining) packaging lines. This can be done by connecting the beginning sections of the cross-docks by a perpendicular chain conveyor with rotating parts at each buffer. Also the cross-docks for packaging line 4 need to be extended to line up with the other cross-docks. The proposed solution is shown Figure 6.8. The connecting conveyor elements are indicated in red.

Figure 6.8: Increase usable buffer space: connecting the cross-docks

The implementation of the solution is not only accomplished by adding the extra conveyor elements. The WMS shall be adjusted accordingly, such that the ‘new’ routes can be used by the system. Also, the WMS shall receive the planning of the packaging lines as an input. Pallets may for example only be transported to another cross-dock if the packaging line connected to it is not planned for production in the coming 1-2 hours.

The effectiveness of this solution may be questioned. If one of the packaging lines connected to the cross-docks is not producing any pallets, the total pallet input to the cross-docks is reduced. This reduction automatically leads to more available over-capacity of the transfer car, hence decreasing the need for additional buffer space.

In this chapter improvements were discussed that could help in achieving the ‘goal’ (alignment of the desired situation with the realisation). The most promising improvement is the capacity increase of the transfer car by means of adding a second one. Although the costs shall be requested by a specialised company, it leads to a yearly saving of over €40.000. Also the time to empty the entire cross-docks after major disturbances decreases to only a third of the original time. In Chapter 7 a conclusion to this research will be provided by providing the answers to the research questions.
This chapter provides an overview of the answer to the research question and the answers to the sub-questions supporting the main research question. This research started with the question:

*How can the loading process at the Zoeterwoude Brewery of HEINEKEN Nederland Supply be improved such that the capacities within the process and corresponding planning are better aligned with the supply of packaging line 2, 4 and 7?*

The answer to this question can be summarised as following. The loading process at the Zoeterwoude Brewery of HEINEKEN Nederland Supply be improved such that the capacities within the process and planning are better aligned with the supply of packaging line 2, 4 and 7 by increasing the capacity of the transfer car between the cross-docks and loading stations and by reducing the number of disturbances caused by a limited availability of containers, human errors and bad communication and planning between internal as well as with external departments / companies. This question was answered by answering five sub-questions. The following answers to these questions were found:

1. **How is the current loading process organised and what factors are of influence on it?**

   The process under study is part of the operations at the Zoeterwoude Brewery of HEINEKEN Nederland Supply. The responsible department is Customer Service & Logistics. CS&L provides the input materials to the packaging lines, but also receives the finished products that come from these packaging lines. The amount of pallets that are being processed by CS&L is growing at a fast rate. Especially loose-loaded pallets carry less boxes and therefore require more pallets for the same volume. The share of these loose-loaded orders increased from 6% in 2012 to 12% in 2014 and is expected to grow even further. When only looking at packaging lines 2, 4 and 7, in 2014, 46%(!) of all shipments were loose-loaded. The process is found to be a complex socio-technological part of the brewery. Process related factors are the arrival of pallets, the cross-dock buffer, the machine capacity, the loading capacity, the arrival of containers, the Warehouse Management System, the availability of machines, the warehouse occupation and the availability of docks.

2. **What data need to be analysed in order to find potential bottlenecks?**

   In order to be able to find potential bottlenecks, data was collected from various sources with different viewpoint of / on the loading process. First of all, data was collected from the actual decisions / actions that were taken in three of the main sub-processes. Second, three data sets were collected on the pallets movements from the full year 2014. Third, the machine status reports from the machines located in the warehouse were collected for the shift with the highest amount of spill-back time. Fourth, relevant data from an internal incident registration system was retrieved and processed. Finally, four interviews were conducted with operators and a warehouse coordinator to find out how the problem is experienced from their point of view.
3. What are the theoretical capacities within the loading process?

The process starts with the input from the packaging lines. It was found that the ‘worst’ product mix produces around 185 pallets per hour. The transfer cars picking up the pallets from the packaging line are able to handle a little more than 68 pallets per hour each. The transfer car between the cross-docks and loading stations can process up to 174 pallets per hour. The capacity of the loading stations is dependent on the type of loading. A capacity of 217 pallets per hour is found when using two loading stations for loose-loaded pallets. The capacity of the loading process is also dependent on the type of loading, but also on the experience of the forklift operators. Two fast operators will process around 225 loose-loaded pallets per hour, whereas two average operators process around 160 pallets per hour. A perfectly aligned arrival of containers leads to a dock capacity of 128 and 96 pallets per hour for packaging line 2 and 7, respectively.

4. What are the causes of the spill-back from the warehouse to the packaging lines?

There are many causes for spill-back on the cross-docks. These small disturbances lead to temporary drops in downstream capacity. The main drivers for major spill-back are a limited capacity of the transfer car between the cross-docks and loading stations (to ensure quick removal after small disturbances), problems with the availability of containers and human errors. Also the lack of skills from some operators, lack of communication between the packaging department and CS&L and the lack of warehouse capacity (required when pallets cannot be loaded immediately).

5. What changes lead to increased system performance and reduced spill-back?

Reducing the input of the cross-docks reduces the number of occurrences of spill-back. A feasible solution would be to limit the flow of cross-dock 41 and 42 by removing the pallets locally in stead of transporting them to one of the expelling tracks. Another solution is to increase to capacity of the transfer car between the cross-docks and loading stations to 263 pallets per hour to take full advantage of the process capacities downstream of this transfer car. Other solutions to reduce spill-back are by introducing strict rules ad penalties regarding late arrival of containers. Also better communication between CS&L and the packaging departments, but also between CS&L and the container terminal. Before starting a new order, it shall be checked if the requested container is still available or if sufficient warehouse capacity is left. Also daily direct communication between the warehouse coordinator and the container terminal leads to less ambiguities regarding the arrival of containers, such that actions can be taken earlier. The number of human errors shall be decreased by providing better training, but also by shifting more responsibilities to the warehouse coordinator (someone with a much better overview of the entire export operation). Increased amount of maintenance to the critical machines lead to increased performance. Lastly, the effects of the disturbances may be tempered by increasing the usable buffer size by connecting the individual cross-docks.

In Chapter 8 recommendations for HEINEKEN Nederland Supply are given regarding the analyses, but also other points of attention found during the research will be discussed.
8

Recommendations

In this chapter recommendations following after the research will be given. The recommendations will consist of recommendations for further research and recommendations based on some findings from the analyses in Chapter 5.

8.1. Recommendations for Further Research

In this section a few recommendations for further research will be provided. These recommendations are related to the provided improvements as well as to other (academic) findings during the research.

If machines are not fully utilised (generally <80%), machines are considered idle. During these idle times, the depreciation of the machine continues. This means that the depreciation of the machine shall be distributed over a smaller amount of products. The extra incurred costs by the proposed improvements is not taken into account during this research. The effects of this phenomena shall be further investigated.

It is also recommended to start any new research on this topic with a simulation of the entire situation. This makes it a lot easier to see what is going wrong and finally to assess the improvements proposed. This was realised during the improvement phase of this research, hence there was not enough time left within the predefined time frame.

8.2. Recommendations for HEINEKEN Nederland Supply

In this section recommendations for HEINEKEN Nederland Supply will be provided. These recommendations will include findings during the research that were not directly related to the problem under study.

The first recommendation is to have a better collection of data. There is a lot of information available regarding the movements each pallet made throughout the warehouse. Limited / no information is available on the exact number of late container arrivals and causes of every individual spill-back towards the packaging lines. It would be much simpler to monitor the process and focus on the right things to improve the loading process. It is also recommended that the different IT systems should be better connected to each other, such that shortcomings / bottlenecks are quicker identified.

One of the issues that was found during the bottleneck analysis was the limited capacity of the transfer cars from the packaging lines towards the cross-docks. Although the problem symptoms were not directly seen at that point, the capacity was found to be insufficient for some product combination of packaging line 21 and 22. For packaging line 7, the transfer car is having a capacity that is just as high as the maximum output of the packaging line at the moment. It is recommended to look into the possibilities and advantages of investing in new transfer cars that have a capacity that leaves sufficient
room for additional movements after a downtime downstream. Two investment options were already proposed by van der Heide (2013). The first solution leads to a capacity of 80 pallets per hour at a cost of €130,000 and the second option leads to a capacity of 100 pallets per hour at a cost of €160,000. The first solution has a capacity that matches the maximum output of the packaging machine, ensuring sufficient capacity with respect to the filling machine. Taking into account that this option is also costs about 20% less, the implementation of this solution is recommended for both packaging lines (2 and 7).

If a trade-off should be made between investing in the transfer cars before the cross-docks or the transfer car after the cross-dock, one should go for the transfer car after the cross-docks. As mentioned earlier, the current total average packaging line output does not add up to the capacities within the process, therefore the investment will only lead to quicker removal of pallets from upstream buffers after disturbances. Since the cross-dock buffer is significantly larger than any other buffer upstream in the packaging lines and since the transfer car serves 5 different packaging lines, the impact of this replacement is much bigger.
References


Appendix: Overview HNS / CS&L

Figure A.1: Organisational Structure HNS with a focus on CS&L
Appendix: Export Warehouse

Figure B.1: Floor plan of export warehouse at CS&L
Appendix: Example Data Overview

Figure C.1: Example Data Overview
Appendix: Internal Incident Registration
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<td>Volloop colonne 7</td>
<td>Container availability</td>
</tr>
<tr>
<td>29-10-14</td>
<td>Volloop colonne 7</td>
<td>Container availability</td>
</tr>
<tr>
<td>30-10-14</td>
<td>Volloop colonne 7</td>
<td>Container availability</td>
</tr>
</tbody>
</table>

**Appendix: Internal Incident Registration 1/2**
Verkeerde container aangevraagd omdat delivery met verkeerde container aangemaakt was
Pallet met rode klos gebroken tijdens beladen van een container. VHT kan pallet niet goed oppakken.
Product het vak in - Verkeerde inspecteur aanwezig
Delivery-6102182-op-schep-ipv-mechanisch-in-delivery
Geen-Mol-20-ft.-4-vrachten-mechanisch-het-magazijn-in
OTA-geen-Maersk-container-20-ft.-meer
Veel-storingen-bij-map-A
Van-1518-tot-1619-3-containers-van-OTA-gekregen
Storing-bij-IB,-weer-het-folie-probleem,-daardoor-volloop
Delivery-6102147-met-verkeerde-aantal-aangemaakt,-dubbel-aantal-dozen
Volloop-colonne-22-2250#2308
Container-met-vreemd-poeder-afgekeurd
Colonne-7-circa-20-minuten-stil-door-volloop
Tussen-1400-en-1530-slechts-5-ledige-containers-ontvangen
Crossdock-colonne-3-(45ft),-colonne-6-en-3-mechanisch-beladen-en-21,-22,-7.-het-kan-konventionele-vervoer-plus--colonne-4.1
Inspecteur-wilde-maar-1-container-tegelijk-inspecteren
Volloop-col2-is-alleen-uzk-op-de-kleine-truck,-mech-station-B-kpot
gene-seatrade
Mondjes-maat-aanvoer-van-containers-of-te-veel-container-aanbod-op-een-moment
1--Container-APL-niet-geleverd-(stond-niet-in-de-nachtstek)
Geen-maersk-1-containers-van-col-22
OTA-heeft-1-container-APL-20-ft.-Tekort-voor-108278-(Col-7)
Geen-HAPAG-20-ft-containers-bij-OTA
OTA-geen-Maersk-container
Geen-hamburg-SUD-DR-meer-beschikbaar-bij-OTA.-NYKE-Del#6094428
6096556-Seagoline-EU-niet-beschikbaar
Containeraanvoer-in-een-golfbeweging-,-dus-volloop-bufferbanen-
4-Containers-truck-blijken-Birge-te-zijn-na-informeren-bij-OTA.-OS-wist-van-niets
8-deliveries--in-voorraad-genomen-geen-containers-beschikbaar
Ernstige-verstoring-belading.-Magazijn-bomvol-en-constant-IB-volbier-binnen-gekregen
Container-in-verkeerde-put-gezet.-Gebruiker:-02033171--L.-Wittenberg
Laadpatroon-niet-ingevuld-in-deliveries-van-code-120425-en-120427
Geen-APL-20ft-voorradig
Geen-Hyundai-20FT-containers-voorradig
Geen-Seado-20-ft-container-voorradig
Col-7-draait-3,5-vracht-,-code-109687,waar-het-zondag-mee-moet-beginnen-volgens-het-charge#overzicht
we-krijgen-ongeveer-een-uur-geen-msc-containers,-ze-hebben-volle-containers-voor-een-boot-met-lege-msc-containers-gezet
Veel-afroepen-in-paars-waardoor-de-banen-vollopen,-door-problemen-kraan-OTA
Geen-cma-meer,-170000-DZN-nog-open.-Mol-geen-documenten,-de-rest-CMA.-Morgen-komt-er-een-boot
Tussen-1600-en-1800-minder-containers-geladen
Deur-dock-1-sluit-niet-automatisch
Inspecteur-nodig-om-15,00-uur--voor-col-7-draaide-code-108320
Deur-dock-2-sluit-niet-automatisch
Deur-dock-1-sluit-niet-automatisch
Deur-dock-2-sluit-niet-automatisch
Deur-dock-1-sluit-niet-automatisch
Deur-dock-2-sluit-niet-automatisch
Deur-dock-1-sluit-niet-automatisch
Deur-dock-2-sluit-niet-automatisch
Deur-dock-1-sluit-niet-automatisch
Deur-dock-2-sluit-niet-automatisch
Deur-dock-1-sluit-niet-automatisch
Deur-dock-1-sluit-niet-automatisch
Appendix: Interviews

Interview 1: Warehouse Coordinator

- What is your specific task within the process of loading of (loose-loaded) containers?
  Coordinating the process of the outgoing goods for export at the Zoeterwoude brewery.

- What is your experience within this loading process?
  I have daily experience for over 10 years, previously I was in the position of forklift driver.

- Are you aware of the spill-back problem during this loading process?
  Yes I am aware of the problem. I am the one who notices spill-back from the beginning.

- Can you point out the most important cause of this problem?
  There is not a single most important problem. Problems do arise when 2 or more production lines deliver pallets for loose-loading. This place is designed for regular loading only. Since 2-3 years loose-loaded products from Den Bosch were moved to Zoeterwoude. Since the number of pallets in a 20-ft (loose-loaded) container is much smaller, multiple docks are reserved per line to preserve a continuous flow. Since only 10 docks are available, some production lines have to wait (causing spill-back).

- Are there any other causes you can think of?
  Yes many, when I was a forklift driver I realised that the transfer car between the crossdocks and loading stations was sometimes not fast enough to deliver a continuous flow of pallets to the loading stations, leading to waiting times for the drivers and spill-back on the buffers. Some problems are also caused by human mistakes (for example by activating the wrong buffer). The availability of containers is also a problem.

- Can you illustrate an example of a moment the problem was present?
  I can not mention a specific point in time this was happening, but as said this mainly happens during the loading of multiple loose-loaded containers (high arrival rate of containers).

- Where / by who is the most hassle experienced?
  Most hassle is experienced at CS&L. Delays lead to an even higher workload and more pallets being stored in the warehouse. Eventually (on the long term) the spill-back causes the filling machine to stop.

- How / by who is the problem in general solved?
  This can be done by locally removing pallets from the production line (before entering the buffer), such that the load for the transfer car is lower. Also by smarter activation of buffers time can be saved.
• Is the provided solution a good solution? Are there other solution you can think of?
  One can think of a different configuration at the end of the crossdocks. The container availability
  can not be neglected, however the process of requesting a container is complex and out of our
  hands.

Interview 2: Forklift Driver
• What is your specific task within the process of loading of (loose-loaded) containers?
  I work in one of the four shifts as a forklift driver for the loading stations.

• What is your experience within this loading process?
  I am very experienced. I train new people on this job as well.

• Are you aware of the spill-back problem during this loading process?
  Yes I am.

• Can you point out the most important cause of this problem?
  Originally hardly any loose-loaded containers. Since 2-3 years very frequently. When multiple
  production lines are producing loose-loaded product, the transfer car between the buffers and
  the loading stations is not able to handle all lines at the same time. This is especially the case
  when line 41 and 42 are producing. These items need to be transported to the expelling tracks.
  It may take up to 30 seconds before 2 new pallets arrive at the loading station (normal load time
  of a container is 15 minutes, in case of limited transfer car capacity 20 minutes).

• Are there any other causes you can think of?
  Yes. The workload is very high when loading loose-loaded containers, un-experienced forklift
  drivers cause breakdowns of loading stations, there are downtimes due to broken pallets (pro-
  truding nails) and the availability of containers.

• Can you illustrate an example of a moment the problem was present?
  Already mentioned as causes.

• Where / by who is the most hassle experienced?
  Spill-back causes the production process to stop (or at least the labelling machine).

• How / by who is the problem in general solved?
  There is not a single solution, however the availability of containers may be evaded by expelling
  the particular order. If there are too many pallets flowing into the buffers, line 41 and 42 are
  emptied earlier in the process.

• Is the provided solution a good solution? Are there other solution you can think of?
  Faster transfer car between the crossdocks and loading stations is the real solution. Also better
  training instructions for new drivers are important. It is impossible to have an extra forklift driver
  for 1 loading station due to limited space.

Interview 3: Forklift Driver
• What is your specific task within the process of loading of (loose-loaded) containers?
  I load the pallets from the loading stations to the containers at the docks (both regular and
  loose-loaded).

• What is your experience within this loading process?
  I am experienced. I do this work for more than five years.

• Are you aware of the spill-back problem during this loading process?
  Yes fully aware.
Can you point out the most important cause of this problem?
Many times we have to wait for the transfer car to deliver a pallet to the loading station. This is the case when line 21/22 and 7 are running loose-loaded orders. If at the same time line 41 and 42 need to be transported to the warehouse (via the expelling track) the transfer car receives too many tasks and cannot keep up with the supply of the buffers.

Are there any other causes you can think of?
The availability of containers and limited warehouse capacity. The limited warehouse capacity may trigger the transfer car to expel pallets to the other side of the warehouse (causing longer travel times of the transfer car).

Can you illustrate an example of a moment the problem was present?
When 3 lines were producing loose-loaded (see cause).

Where / by who is the most hassle experienced?
Most hassle is experienced by the forklift drivers in the warehouse. Pallets that are stored need double the amount of movements compared to pallets that are directly stored in a container.

How / by who is the problem in general solved?
The problem is not really solved. The effects can be only be limited by expelling entire orders.

Is the provided solution a good solution? Are there other solution you can think of?
No, but in practice the only one available. Structural changes to the transfer car will anyway lead to less problems.

Interview 4: Forklift Driver
What is your specific task within the process of loading of (loose-loaded) containers?
I am a forklift driver for the export warehouse.

What is your experience within this loading process?
I work here for many (5+) years 8 hours per day.

Are you aware of the spill-back problem during this loading process?
Yes I recognise the problem.

Can you point out the most important cause of this problem?
It happens that we have to wait for the pallets. This is due to the speed or probably route choice of the transfer car between the buffers and loading stations.

Are there any other causes you can think of?
Waiting for containers is another problem. Normally an order can be expelled to the warehouse, however when line 41 and 42 are also producing the travel distances of the transfer car increase. At some point the transfer car cannot keep up with the production.

Can you illustrate an example of a moment the problem was present?
Last week there were three lines producing loose-loaded batches, while at the same time the 41 and 42 were producing.

Where / by who is the most hassle experienced?
At the packaging departments.

How / by who is the problem in general solved?
Trying to limit the pallets by removing the pallets of line 41 and 42 locally.

Is the provided solution a good solution? Are there other solution you can think of?
No, it does reduce the chance of spill-back, but it is not how the process is supposed to be.
# Appendix: Packaging Lines Output

Table F.1: Packaging line product output details

<table>
<thead>
<tr>
<th>Line</th>
<th>Bottle</th>
<th>Bottles/box</th>
<th>Occurrence</th>
<th>Avg. boxes / pallet</th>
<th>Min. boxes / pallet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>207HK</td>
<td>24</td>
<td>10%</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td>250K2</td>
<td>24</td>
<td>39%</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>250K2 LO</td>
<td>24</td>
<td>24%</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>330K2</td>
<td>24</td>
<td>4%</td>
<td>82</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>330K2 LO</td>
<td>24</td>
<td>10%</td>
<td>56</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>355K2</td>
<td>24</td>
<td>12%</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>355K2 LO</td>
<td>24</td>
<td>0.5%</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>330K2</td>
<td>24</td>
<td>7%</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>330K2 LO</td>
<td>24</td>
<td>11%</td>
<td>56</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>355K2</td>
<td>24</td>
<td>0.4%</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>355K2 LO</td>
<td>24</td>
<td>5%</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>650K2</td>
<td>12</td>
<td>32%</td>
<td>89</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>650K2 LO</td>
<td>12</td>
<td>44%</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>22</td>
<td>330K2</td>
<td>24</td>
<td>19%</td>
<td>83</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>330K2 LO</td>
<td>24</td>
<td>48%</td>
<td>54</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>355K2</td>
<td>24</td>
<td>7%</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>355K2 LO</td>
<td>24</td>
<td>1%</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>330SOL</td>
<td>24</td>
<td>17%</td>
<td>68</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>330SOL LO</td>
<td>24</td>
<td>8%</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>
Appendix: MATLAB Model of Cross-Docks

This appendix provides more details on the model that is being used to assess the increase of the transfer car capacity. The model assumptions, inputs and outputs and the verification and validation is discussed.

Model Assumptions
The following model assumptions / simplifications are made:

- The model works with an average capacity and does not deal with the fact that the transfer car takes two pallets at a time, leading to less accurate increases / decreases per time step.
- The model does not take into account decisions from the operators. In the simulation all packaging lines are ‘activated’ at the same time. This may change the outcome by having some buffers to grow at certain times and others to shrink faster than shown in the figures.
- The model works with a proportionally shared capacity of the transfer car, hence if the line input is zero, but there are still pallets on the crossdocks, the pallets are not removed by the model.
- The model does not account for temporary breakdowns of machines, shift relays or any other form of a temporary capacity drop.

Model Inputs and Outputs
The model can work with the output of the packaging lines as an input. This input can be in the form of a vector, such that a temporary peak or drop in production can be modelled too. The machine capacities are variables as well and can be adjusted to represent the current or future conditions (depending on the desired comparison). The model automatically determines if an upstream capacity is higher than its downstream follower, such that the flow of pallet is reduced to the ‘constraints’. The output of the model is a plot showing the development of the buffer occupation over time. The model is a deterministic model. A deterministic model will always produce the same output from a given starting condition or initial state. Only user input will produce different solutions.

Model Verification and Validation
The model is build in such a way that the intermediate calculations can be seen as well after running the code. This allows the user to assess if the right numbers are used and if the calculations are done properly. If an error is observed it is easy to trace back to origin of the wrong number or calculation. The same approach was used to verify the outcomes from the model scenarios that will be described later on. The model is a straightforward calculation model and does not account for disturbances as mentioned earlier. The model shall be used as tool to compare the results in an ideal situation.
case there are disturbances the output will be different. Since it is not exactly known at the moment how often and how long the disturbance take, it is not possible to validate the model with the practical situation.

**MATLAB Code of Model**

```matlab
% This script makes a simplified graphical representation of the buffer
% occupation at the crossdocks attached to packaging line 2, 4 and 7 of the
% Zoeterwoude Brewery of HEINEKEN Nederland Supply. The model input shall
% be adjusted before using this model.

% INITIALIZE VARIABLES

% Initialize crossdocks
CD21 = zeros(600,1);
CD22 = zeros(600,1);
CD7 = zeros(600,1);
CD41 = zeros(600,1);
CD42 = zeros(600,1);

% Initialize crossdock inputs
Input21 = zeros(600,1);
Input22 = zeros(600,1);
Input7 = zeros(600,1);
Input41 = zeros(600,1);
Input42 = zeros(600,1);

% Initialize crossdock outputs
Output21 = zeros(600,1);
Output22 = zeros(600,1);
Output7 = zeros(600,1);
Output41 = zeros(600,1);
Output42 = zeros(600,1);

% Initialize accumulation of crossdocks
Accumulation21 = zeros(600,1);
Accumulation22 = zeros(600,1);
Accumulation7 = zeros(600,1);
Accumulation41 = zeros(600,1);
Accumulation42 = zeros(600,1);

% Initialize total input and output variables
InputCD = zeros(600,1);
OutputCD = zeros(600,1);
TotalOutput = zeros(600,1);

% Initialize packaging line speeds
Speed21 = zeros(600,1);
Speed22 = zeros(600,1);
Speed7 = zeros(600,1);
Speed41 = zeros(600,1);
Speed42 = zeros(600,1);

% MODEL INPUTS

% Input packaging line speeds
Speed21(1:600) = 23/60;  % Speed21
Speed22(1:600) = 25/60;  % Speed22
Speed7(1:600) = 39/60;   % Speed7
```

---

**Explanation:**

This MATLAB script models a simplified graphical representation of the buffer occupation at crossdocks attached to packaging lines 2, 4, and 7 at the Zoeterwoude Brewery of HEINEKEN Nederland Supply. The model is intended for use with practical situations, although the input parameters must be adjusted before the model can be used. The script initializes variables for crossdocks, input flows, output flows, and accumulation of crossdocks. It also includes initialization of total input and output variables and packaging line speeds. The script concludes by defining the speeds of the packaging lines for lines 2, 22, and 7, with specific rates for each speed. These rates are used to simulate the expected flow rates for the packaging lines, which can be adjusted according to the actual speeds of the lines.
% Input capacity transfer cars packaging lines
CapacityTC2 = 68.4/60;
CapacityTC7 = 68.4/60;
CapacityTC4 = 68.4/60;

% Input initial buffer occupation
CD21(1) = 42;
CD22(1) = 42;
CD7(1) = 84;
CD41(1) = 0;
CD42(1) = 0;

% Input capacity transfer car after crossdocks
CapacityTCX = 263/60;

% Determine crossdock inputs and outputs
for j = 1:600
    if CapacityTC2 < Speed21(j) + Speed22(j)
        Input21(j) = (Speed21(j)/(Speed21(j) + Speed22(j))) * CapacityTC2;
        Input22(j) = (Speed22(j)/(Speed21(j) + Speed22(j))) * CapacityTC2;
    else
        Input21(j) = Speed21(j);
        Input22(j) = Speed22(j);
    end

    if CapacityTC7 < Speed7(j)
        Input7(j) = CapacityTC7;
    else
        Input7(j) = Speed7(j);
    end

    if CapacityTC4 < (Speed41(j) + Speed42(j))
        Input41(j) = (Speed41(j)/(Speed41(j) + Speed42(j))) * CapacityTC4;
        Input42(j) = (Speed42(j)/(Speed41(j) + Speed42(j))) * CapacityTC4;
    else
        Input41(j) = Speed41(j);
        Input42(j) = Speed42(j);
    end

    InputCD(j) = Input21(j) + Input22(j) + Input7(j) + Input41(j) + Input42(j);

    if InputCD(j) > CapacityTCX
        OutputCD(j) = CapacityTCX;
    else
        OutputCD(j) = CapacityTCX;
    end

    Output21(j) = (Input21(j) / InputCD(j)) * OutputCD(j);
    Output22(j) = (Input22(j) / InputCD(j)) * OutputCD(j);
    Output7(j) = (Input7(j) / InputCD(j)) * OutputCD(j);
    Output41(j) = (Input41(j) / InputCD(j)) * OutputCD(j);
    Output42(j) = (Input42(j) / InputCD(j)) * OutputCD(j);
Appendix: MATLAB Model of Cross-Docks

Output41(j) = (Input41(j) / InputCD(j)) * OutputCD(j);
Output42(j) = (Input42(j) / InputCD(j)) * OutputCD(j);

TotalOutput(j) = Output21(j) + Output22(j) + Output7(j) + Output41(j) + Output42(j);

% Determine crossdock accumulation
Accumulation21(j) = Input21(j) - Output21(j);
Accumulation22(j) = Input22(j) - Output22(j);
Accumulation7(j) = Input7(j) - Output7(j);
Accumulation41(j) = Input41(j) - Output41(j);
Accumulation42(j) = Input42(j) - Output42(j);

end

% Make sure that the maximum and minimum (zero) buffer size is not exceeded
for i = 2:600
    if CD21(i-1) < (42 - Accumulation21(i-1))
        CD21(i) = CD21(i-1) + Accumulation21(i-1);
    else
        CD21(i) = 42;
    end
    if CD21(i) < 0
        CD21(i) = 0;
    end
    if CD22(i-1) < (42 - Accumulation22(i-1))
        CD22(i) = CD22(i-1) + Accumulation22(i-1);
    else
        CD22(i) = 42;
    end
    if CD22(i) < 0
        CD22(i) = 0;
    end
    if CD7(i-1) < (84 - Accumulation7(i-1))
        CD7(i) = CD7(i-1) + Accumulation7(i-1);
    else
        CD7(i) = 84;
    end
    if CD7(i) < 0
        CD7(i) = 0;
    end
    if CD41(i-1) < (42 - Accumulation41(i-1))
        CD41(i) = CD41(i-1) + Accumulation41(i-1);
    else
        CD41(i) = 42;
    end
    if CD41(i) < 0
        CD41(i) = 0;
    end
    if CD42(i-1) < (42 - Accumulation42(i-1))
        CD42(i) = CD42(i-1) + Accumulation42(i-1);
    else
        CD42(i) = 42;
    end
    if CD42(i) < 0
        CD42(i) = 0;
    end
end

% Plotting

t = 0:599;
axis([0 599 0 inf])
xlabel('Time (minutes)')
ylabel('Buffer occupation (# of pallets)')
hold on
plot(t, (round(CD21)))
plot(t, (round(CD22)))
plot(t, (round(CD7)))
plot(t, (round(CD41)))
plot(t, (round(CD42)))

annotation('textbox', [0.43, 0.85, 0.3, 0.05], ...
'String', ['Input crossdocks = num2str(InputCD(1)*60) ' pallets/h'])

annotation('textbox', [0.43, 0.77, 0.3, 0.05], ...
'String', ['Output crossdocks = num2str(CapacityTCX*60) ' pallets/h'])

legend('CD21', 'CD22', 'CD7', 'CD41', 'CD42')
grid on